DISPLAY WEEK 2012 REVIEW ISSUE

Information DISPLAY

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July/August 2012
Vol. 28, Nos. 7 & 8

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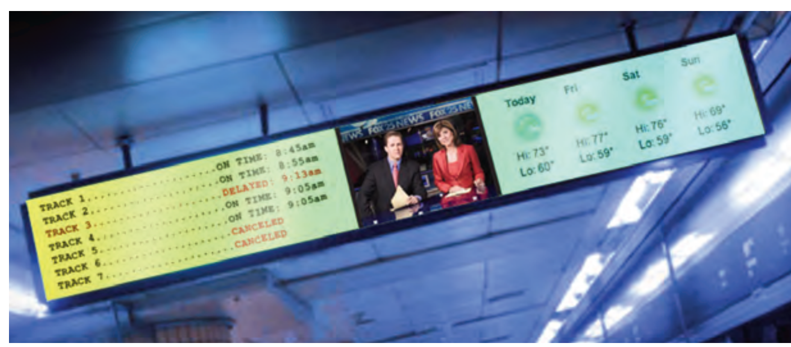

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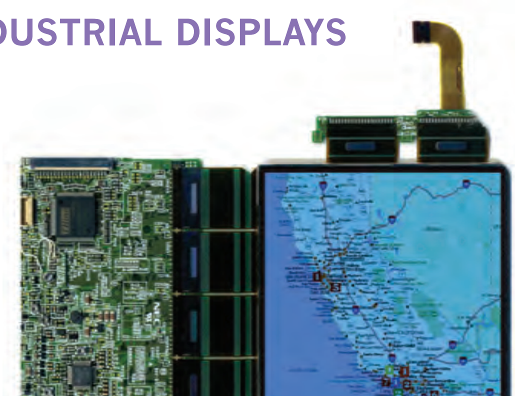

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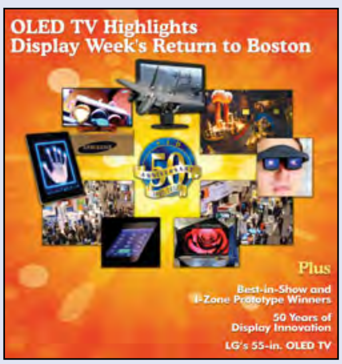
ON THE COVER: *The cover features the winners of the Best-in-Show Awards, the winner of the first-ever Best Prototype from the Innovation Zone at Display Week, and scenes from Display Week 2012 in Boston. From top center, clockwise: Dimenco's multi-view 3-D display (BIS); the special event at the Boston Museum of Science; Fraunhofer COMEDD's AMOLED microdisplay with integrated photosensor (BIS); exhibit hall floor; LG Display's 55-in. AMOLED TV with white OLEDs and oxide backplane (BIS); Tactus Technology's tactile touch-screen interface (Best I-Zone Prototype); exhibit hall floor; Ocular's 17-in. projected-capacitive multi-touch panel (BIS); Samsung's 55-in. AMOLED TV with RGB OLEDs and LTPS backplane (BIS).*



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Next Month in *Information Display*

Touch Technology

- Display Week Touch Technology Review:
- What's Happening in Projective-Capacitive?
- Front-of-Screen Treatments
- The Touch-Controller Market
- Laser Patterning of Silver Nanowire
- 50th Anniversary of SID: Part II

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editorial

Celebrating 50 Years and Counting

by Stephen Atwood

It's hard to believe that we're about to celebrate the 50th anniversary of the birth of the Society for Information Display. A lot has happened in 50 years and to fully appreciate it, I guess you would have had to have lived it all the way through. Of course, I haven't had that privilege. I was less than a year old when the first SID chapter meeting was held in Los Angeles on the campus of UCLA in September of 1962. But there are still many people around who were there at that first meeting or who joined in the nascent next few years, and it is through their thoughtful recollections, combined with the work of several great contributing writers, that we're able to bring you this issue containing articles that celebrate the history of display technology.

The 50th Anniversary of the first SID meeting will be commemorated by a one-day technical and business conference titled "Displays and Technologies for the Future" on Sept 29, 2012 right at SID's birthplace, the UCLA campus in Los Angeles, CA. After a great day of technical presentations there will be a ceremony and plaque presentation along with a President's reception and banquet dinner. The full details and registration information can be found in the centerfold of this issue.

To get the full measure of how far we've come in 50 years with some of the key display technologies, we asked a few of the most experienced people in this industry to give us a perspective on the origins of various display technologies. Larry Tannas artfully summarizes the highlights of LCDs by pointing out the most significant achievements along the way, such as the invention of the active-matrix addressed panel. This is further expanded by a look at all the work done in the UK to further the fundamental technology of liquid crystals for displays, carefully recalled for us by Myrddin Jones. Larry Weber describes the early history of plasma technology and the original motivation for pursuing it as a research topic and then later as a commercial product. Chris Curtin takes on the ubiquitous CRT, which was already enjoying commercial success by the time SID was founded, and Matt Brennesholtz gives us a great look at the early days of projection technology, which went way beyond just very bright CRTs, even in the 1930s. SID past-president Munisamy Anandan, partnering with renowned expert Amal Ghosh, describes the seminal moments in the evolution of OLED displays, which have been the most significant headline grabbers these past few months. Putting this all together for us, Jenny Donelan found that the origins and evolution of the various pieces all followed somewhat similar paths that were marked by short bursts of demonstrated progress and then long periods of intense research, with occasional false starts and struggles along the way. We all know about the commercial successes that were achieved, but it's more interesting to ponder the countless lifetimes' worth of hard work and thoughtful innovation carried out quietly in the background that formed the basis for these achievements. My admiration and respect goes out to all the great inventors and innovators who brought this industry to where it is today.

But while the past is prologue, the present is where the action is, and there was no shortage of excitement at Display Week 2012 in Boston, MA. As we do every year, we bring you a full review of the most interesting things seen and heard at Display Week, written by our highly qualified team of guest reporters: Dr. Jason Heikenfeld with the University of Cincinnati for e-Paper; *ID* contributing editor Steve Sechrist for 3-D technology; Sung Kim and Barry Young of the OLED Association for OLEDs; and *ID* contributing editor Alfred Poor for LCDs. Collectively, this team captured a

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Microsoft to Acquire Perceptive Pixel, Inc.

by Jenny Donelan

In early July, Microsoft and multi-touch display company Perceptive Pixel, Inc. (PPI) announced that Microsoft would acquire PPI under terms not yet disclosed. Perceptive Pixel was founded in 2006, and shipped its first products – multi-touch workstations and large wall displays – in early 2007. As has been reported elsewhere, the giant touch displays first came to widespread notice when they were used by CNN and other television networks for coverage of the 2008 U.S. presidential election.

This year, PPI's 82-in. projected-capacitive (pro-cap) LCD with multi-touch and stylus input received a Silver Award in the category of Display Application of the Year from the Society for Information Display. According to the Display Industry Award article in the May/June issue of *Information Display*, projective-capacitive sensing is very difficult to scale to larger displays; this is why PPI's implementation was an impressive achievement. That article stated: "In August of 2011, Perceptive Pixel introduced the first large-scale pro-cap interactive display that achieves the level of fidelity and performance necessary for real productivity … featuring true full-frame unlimited finger touch and precision stylus sensing at 120 Hz across a proprietary sensor that is optically bonded to an 82-in. LCD panel."

PPI was founded by active SID member Jeff Han, who was called the "The Master of Touch." by *ID* Contributing Editor Geoff Walker in a Display Week 2012 blog on www.informationdisplay.org. Walker wrote: "Jeff consistently has the clearest vision of how touch needs to evolve to allow professionals to accomplish real work using touch, and he articulates that vision with exceptional clarity. Perceptive Pixel is not a touch-screen company – although it does make and sell a high-end 27-in. touch monitor; it's a company dedicated to inventing solutions to user-interface problems in the knowledge-worker world."

Clearly, these solutions to interface problems did not go unnoticed by Microsoft. What's less clear is what the software giant intends to do with the technology. Microsoft has shown an interest in hardware, announcing its own Surface tablet last June. In an article titled "Inside Microsoft's Brilliant Acquisition of Perceptive Pixel," Datamation author Mike Elgan suggests that Microsoft may indeed sell PPI's relatively high-end displays, but also offer PPI's APIs and technology to OEM partners. "On the software front," writes Elgan, "PPI makes an impressive application called Storyboard, which is a type of multi-touch, multi-user PowerPoint on steroids. The announcement by Microsoft seemed to focus heavily on the Microsoft Office group and the benefits thereto. So it's a safe bet that Storyboard may be integrated with PowerPoint and that Office apps will get strong multi-touch features." He continues: "Although Microsoft has developed a lot of multi-touch and gesture-control technology in-house, PPI is also a leader in this field. With that technology come some nice patents."[1]

Han was not able to discuss the details of the transaction, but did say: "This merger is really, really significant. Joining Microsoft highly empowers us to accelerate our vision unchanged and allows for our displays to soon become completely ubiquitous: in every meeting room, every office, and every classroom. Perhaps even more importantly, we're specifically within the Office Division, and the integration of PPI's rich software and interaction techniques into the full Office suite of applications will provide the complete solution that's absolutely required for such widespread adoption, across all form factors." Han, who is President and CTO of PPI as well as its founder, will join Microsoft as a general manager and will be reporting directly to Kurt DelBene, President of the Office Division.

References

[1]http://www.datamation.com/data-center/inside-microsofts-brilliant-acquisition-of-perceptive-pixel-1.html

Samsung Display Company Launches

It's official. Samsung Display Co., Ltd., announced in July that it has begun conducting business as a newly merged corporation of Samsung Mobile Display and S-LCD corporations. The company says it is now the world's largest display manufacturer, with 39,000 employees and seven production facilities worldwide. For more about the reorganization, see the Industry News article, "Samsung Announces Industry Spinoff," in the April 2012 issue of *Information Display* magazine. ■

I-Zone and Best-in-Show Winners

The Society for Information Display honored six companies at Display Week 2012: Tactus Technology for best prototype in the new Innovation Zone and Dimenco, Fraunhofer COMEDD, LG Display, Ocular, and Samsung Display Company as Best-in-Show winners from the exhibit floor.

by Jenny Donelan

DISPLAY WEEK featured a new kind of exhibition within the exhibition this year – the Innovation Zone (I-Zone). The 23 exhibitors in the designated I-Zone space were chosen to participate on the basis of their cutting-edge research and their ability to demonstrate a working prototype at the show. The presence of these companies, many of them start-ups or research arms of larger institutions, enhanced the entrepreneurial aspect of Display Week and also gave show-goers a look at display technologies of the future.

I-Zone Prototype Winner: Tactus Technology, Inc.

Members of the I-Zone committee chose the best prototype from the I-Zone, announcing the winner, Tactus Technology, Inc., right on the show floor for its next-generation tactile touch-screen interface. The technology enables touch screens with buttons or other shapes that rise from the surface of the screen when needed and recede when not, leaving a flat surface (Fig. 1). The Tactile layer panel uses microfluidics to produce the physical buttons and adds no extra thickness to a standard touch-screen display.

Best-in-Show Winners

Five companies – Dimenco, Fraunhofer COMEDD, LG Display, Ocular, and Samsung – won Best-in-Show awards at Display Week, the 49th annual SID International Symposium, Seminar, and Exhibition held in Boston last June. The 2012 winners were selected by a panel of display experts based on the significance of their development and/or product and for their ability to generate excitement within not only the display industry but also the general public and the media. The awards were open to all exhibitors on the show floor during Display Week 2012.

The Best-in-Show distinction allows SID to honor those developments that are often first showcased at Display Week, according to Robert Melcher, chairman of the awards committee. Says Melcher, "We were pleased to recognize five standout products from the impressive and diverse field on the exhibit floor."

Dimenco received a Best-in-Show award for its unique 23-in. eye-tracking, auto-adjusting stereo, and multi-view 3-D display (Fig. 2) and its large-area 56-in. multiple-view 4K × 2K display. Dimenco's glasses-free technology is based on a patented lenticular-lens technology designed to eliminate banding effects while providing a 150° viewing angle and 28 views. For more about Dimenco's autostereoscopic display, see the Display Week Technology review on 3-D in this issue.

Fraunhofer COMEDD earned the Best-in-Show award for its AMOLED microdisplay with integrated photosensor, which could be

Fig. 1: Tactus Technology's tactile user interface uses microfluidics to create physical buttons that rise up from the surface of the screen on demand and recede back into the screen when no longer needed.

Fig. 2: The 23-in. autostereoscopic display from Dimenco offers 28 views.

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Fig. 3: System designer Rigo Herold wears Fraunhofer COMEDD's interactive data glasses.

applied for next-generation eye-tracking devices. The glasses shown at Display Week (Fig. 3) are designed to enable the user to view the real world while also being able to see virtual information. The embedded camera in the microdisplay captures the eye movements of the user to allow interaction with and control of the virtual information in a manner similar to a mouse.

LG Display earned a Best-in-Show award for its 55-in. 3-D OLED TV with WRGB OLEDs and an oxide backplane in a thin form factor (Fig. 4). The TV represents a huge achievement in terms of large-sized OLEDs and also offers 3-D viewing with a film-patterned retarder and low-cost glasses. For more about this product, see the OLED Technology review in this issue.

Ocular was named a Best-in-Show winner for its 17-in. projected-capacitive multi-touch panel that supports 16 simultaneous touches (Fig. 5). This true multi-touch panel features the Atmel maXTouch mXT1716E controller and measures 400 mm × 258 mm. While supporting the 16 touches, it also has the sophistication to identify and disregard unintended touches.

Fig. 4: LG Display's 55-in. OLED TV was a show stopper at Display Week, as was Samsung's version of a 55-in. OLED.

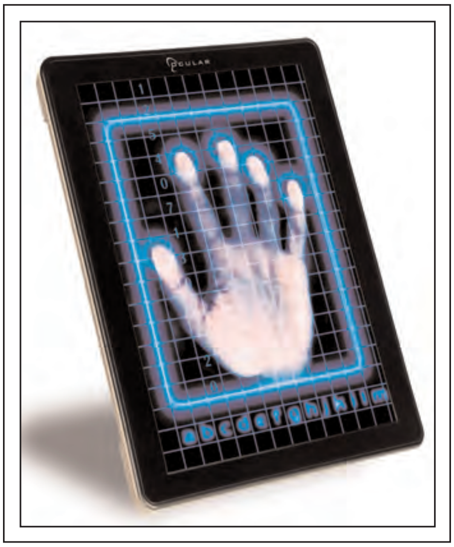

Fig. 5: Ocular's 17-in. pro-cap panel supports up to 16 simultaneous touches.

Samsung was named a Best-in-Show winner for its impressive 55-in. AMOLED TV with true RGB OLEDs and LTPS backplane, and dual-view feature (Fig. 6). Samsung's 55-in. TV has an active 3-D design that preserves resolution and luminance with no crosstalk, using glasses that are much lighter and more comfortable than earlier 3-D counterparts. See more about this TV in the OLED Technology Review in this issue. ■

Fig. 6: Samsung's 55-in. 3-D OLED TV also offers a dual-view feature that allows two people to watch the same set simultaneously while seeing and hearing different content.

Display Week 2012 Review: e-Paper

Major corporate bets are already placed, but new breakthroughs abound at the Symposium.

by Jason C. Heikenfeld

IN PERSPECTIVE, let's start this year's review of e-Paper at Display Week with the last few lines from my previous year's review (in the July/August 2011 issue of *Information Display*): "Looking forward to next year, will we have color modules from E Ink (electrophoretic), Bridgestone (liquid powder), Qualcomm (mirasol), and Samsung (electrowetting) in the marketplace? … Next year should be a critical one for accessing the ability of e-Paper to move beyond signage and e-Readers."

Well, this past year, both mirasol and initial color-electrophoretic modules did appear in limited distribution in a few markets, while Bridgestone exited the race and electrowetting progress has been ultra-quiet since Samsung acquired the technology. Just for evaluation purposes, I purchased an electrophoretic Jetbook color e-Reader and Mirasol Kyobo e-Reader. No one I have talked to believes they provide highly compelling color, but if battery life and sunlight readability are important, and you need color and/or video content displayed, then they of course look much better than an iPad would in sunlight – or with a dead battery! Qualcomm remains tenacious in pushing mirasol into the market; the key question is whether the company can achieve the volume of sales needed to justify the billions of dollars it has invested.

Last year, my article was highly fixated on color and video – maybe too much. We should not forget the continued success of monochrome e-Readers and the strong growth in applications such as electronic shelf labels. However, rather than continue to speculate on where we are today or where we are heading next, let's instead turn our attention to what I actually saw at Display Week this year. There were examples of exciting R&D progress, which I'll get to, but first I'll cover the relatively more mature technologies.

On the exhibition floor, the demonstrations were mostly of technologies seen in the past, with even a few expected developments missing. For example, the E Ink prototypes were expanded in types of applications shown (more shelf-labels/signage for example), but R&D demos with significantly higher reflectivity than last year were absent (see Fig. 1 for a look at just some of the many modules on display at E Ink's booth).

E Ink's progress toward animation and video continues. The video demos sneak in visually obvious reset frames after several video frames, and display expert Ken Werner summed it up best: "For kids' cartoons, the motion was smoother than I would have expected, but you could tell that at this point it costs them a significant loss in contrast."

Fig. 1: Walls of monochrome and color electrophoretic modules were on display at the E Ink booth, demonstrating that the expansion of applications for this technology continues. Photo courtesy the author.

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Qualcomm was showing somewhat improved mirasol video-rate modules, with statements of improved performance that I cannot confirm or validate, only quote: "a 5.7-in. enhanced XGA display – this is the core in the four commercially launched products, but with doubled contrast ratio, improved brightness and color saturation, frame rate (continual 30 fps), and energy efficiency that would increase battery life by about 20% (to almost one month)." mirasol was awarded the Display of the Year Silver Award at the show, in recognition of commercial advances in sunlight readability and reduced power consumption.

For a second year, Opalux was exhibiting its photonic ink or P-Ink technology. This technology shows a clever advantage that it shares with other electrochemical-type displays (such as electrochromic), integration with RFID, which leverages the extremely low-voltage and current-driven nature of such devices (Fig. 2). One has to remember that screen performance is important, but ease of design into various products/devices can be a compelling advantage as well. Another great example is electrochromism in smart cards; they can be integrated as manufacturers prefer, using hot lamination. (For more about the P-Ink technology, see "Photonic-Crystal Display Materials" in the July/August 2011 issue of *Information Display*.)

Fig. 2: *Opalux photonic crystal ink is electrochemically actuated using voltage low enough for RFID powering. Photo courtesy the author.*

Overall this year, the e-Paper exhibits were certainly worthwhile to gauge the existing pulse of commercial and near-commercial technology. In general, you could argue in some respects that it was also a somewhat disappointing year on the commercialization end. In addition to the Bridgestone exit of liquid-powder technology, one of the great advantages and hopes for e-Paper seems to be stalled out: rollable displays. Polymer Vision, which has shown perfect-looking rollable monochrome rollable/foldable displays for some time now, is downsizing and in need of investors yet again. Hopefully by the time this article hits the press, the company will be back on-track financially. Furthermore, this spring Plastic Logic announced another delay and pull-back in commercialization of tablets and e-textbooks. The company is instead focusing on industrial and other uses for its flexible screens, in areas where a flexible, durable, and low-power display might command greater margin. Again, on the product end we may need to be satisfied for the time being with existing simple monochrome success. After all, E Ink continues to expand its R&D workforce, to the point where it has had to move to a new, larger facility near Boston. So where to go from here?

If you were looking for excitement, I hope you did not miss the Symposium, which was well worth the trip to Display Week on its own. There were numerous papers describing real leaps (not increments) in reflective brightness and saturated color. Fuji Xerox presented a multi-color particle CMY subtractive electrophoretic display that showed dramatically improved color. Naoki Hiji of Fuji, a long-time SID presenter known for his unique innovative approaches to e-Paper, gave the talk. His author-interview session had a live demo unit [Fig. 3(a)] and was extremely crowded, with viewing opportunities only available to those patient and athletic enough to slowly nudge/cram their way to the front. However, the wait to see the prototype was worth it; it looked as colorful as billed [Fig. 3(b)] and was remarkably functional for a first active-matrix prototype. The improvement over conventional side-by-side RGBW color filter is obvious and significant.

The prototype was only for red/cyan color, with single-pixel full-CMY-color operation reported in the Digest paper. The display had 30% reflectance and showed color over 100% of the area instead of 25% of the area for RGBW. I was particularly impressed with the quality of the black state for a first demo;

(a) (b)

Fig. 3: *(a) Zoom-out and (b) zoom-in photos show Fuji-Xerox's multi-colored particle EPD demonstrator using red/cyan particles. The improvement over the conventional RGBW approach was visually striking. Photo (a) courtesy the author. Photo (b) courtesy Fuji Xerox.*

however, getting a good black with additional mixed colors might require a lot of work. I hope to see the full-color version next year. Deservedly, this paper "Novel Color Electrophoretic e-Paper Using Independently Movable Colored Particles" received a coveted Distinguished Paper Award from SID.

All of a sudden, there is very strong momentum in CMY subtractive color generation for e-Paper. It has always been known that this is theoretically the most likely approach to achieve bright and colorful e-Paper, but working pixel designs were lacking in the past. This is rapidly changing. For example, just last year Ricoh showed at Display Week a breakthrough CMY electro-chromic module. The Fuji electrophoretic and Ricoh electrochromic CMY modules also share a major breakthrough; they can operate using a *single* active-matrix backplane. Even though their pixel physics are very different, they also both use a 4-cycle clear/write frameset to build the image. Because they require only a single active-matrix backplane, achieving high resolution and low cost is a real possibility.

Advances in CMY subtractive color e-Paper were also presented by Hewlett-Packard for three layers of active-matrix modules stacked together. Such an approach is clearly limited to low resolution, but the color performance can be quite compelling for billboards and signage. HP's title for its paper and talk was bold but said it all: "Ultra-Low-Power Reflective Display with the World's Best Color." Each active-matrix layer has 0.5-mm pixels with a 94% clear aperture. Each of the three layers compacts or spreads C, M, or Y pigments through electrokinetics. The color performance for both in- and off-axis lighting is very close to SNAP (Specifications for Newsprint Advertising Production) standards and the color is entirely in another league compared to RGBW on electrophoretic or mirasol [Figs. 4(a) and 4(b)]. However, it is important to remember that this performance is limited to medium- and low-resolution displays. HP's rapid technical progress in electrokinetic technology has been tremendous. The technology may be approaching the next hurdle of commercial adoption.

One way to improve the performance of more conventional RGBW displays is simply to find the best black/white shutter – hopefully one that demonstrates video speed since none of the hot CMY approaches can do video. So, turning attention back to single-layered monochrome (which, after all, is the only widely accepted e-Paper product), I gave an invited presentation on a new "electrofluidic imaging film" that can be laminated like E Ink, switches at 12 msec, and is calculated to provide >80% white reflectance. This is a highly novel approach, partly because it is the first fluid or colorant-moving display that operates with no pixel borders or ink encapsulation. If an RGBW color filter is placed on this, it would be as bright as the widely accepted monochrome E Ink but with the addition of color and video. In fairness, however, I have to mention that this approach is brand new (less than a year old), is still causing my students and me sleepless nights just like a newborn baby would, and remains in development with regard to attributes such as gray-scale generation. My talk did lead to many interesting discussions, especially with the numerous companies accustomed to the ease of lamination integration of E Ink.

Outside the exhibit and Symposium, it was encouraging to see strong attendance at the 90-minute e-Paper seminars on Monday

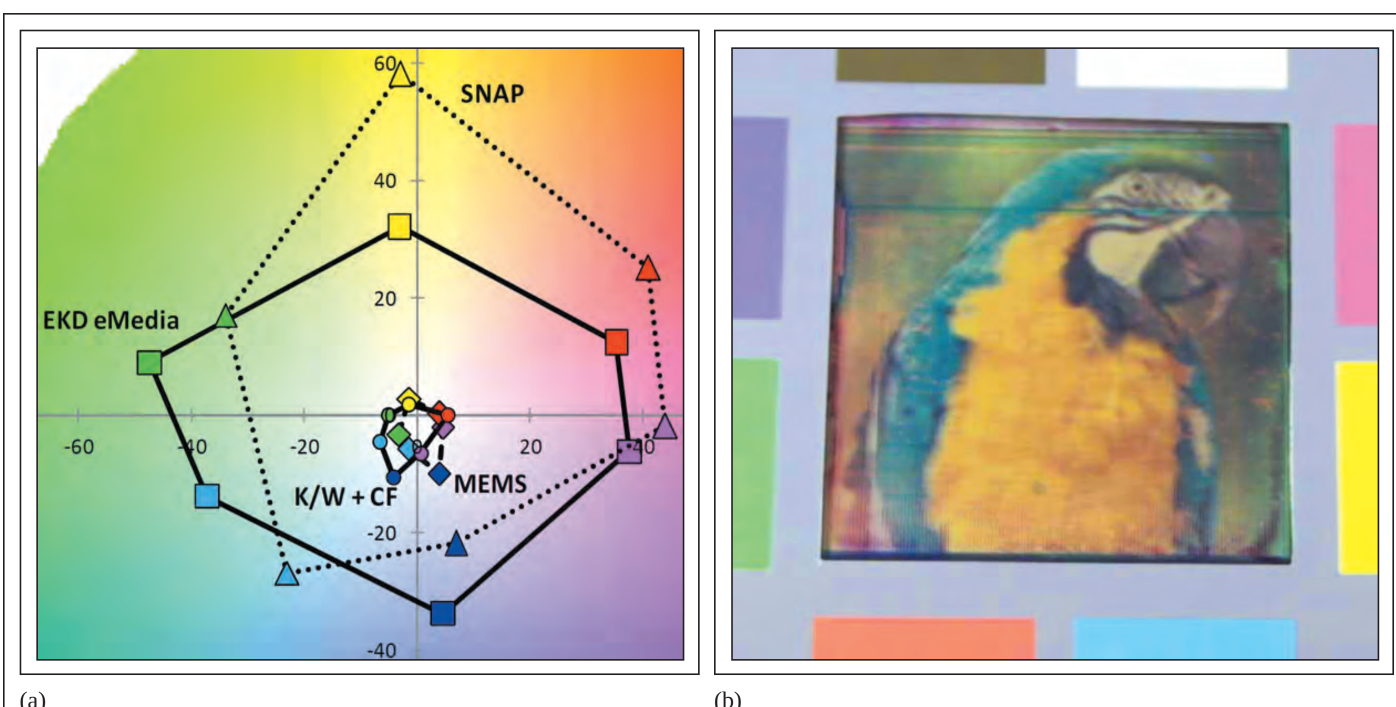

Fig. 4: *HP's progress in color e-Paper is evidenced by (a) a plot of maximum color space compared to existing approaches such as RGBW E-Ink or RGB MEMS (Qualcomm mirasol) and (b) a working prototype surrounded by high-quality color printing on paper.*

90-minute e-Paper seminars on Monday (I gave one on the present and future prospects for electronic paper; Russel Martin from Qualcomm gave one on displays for e-Readers). Also, it was encouraging that Janglin Chen, Vice President of Industrial Technology Research Institute (ITRI) in Taiwan, and the General Director of ITRI's Display Technology Center, was given a Special Recognition Award from SID *"For his leading contributions to the development of hybrid plastic substrates for flexible displays and electronics and for the development of rewritable and reusable electronic paper."* AUO presented a nice poster on an e-Paper module with a photovoltaic integrated on the back side. Some implementations of e-Paper are indeed so power efficient that plugs for charging are not needed.

As always, it is impossible to cover all the e-Paper seen at Display Week 2012 in this brief article. The diversity of players in the e-Paper race remains large, with a few companies leaving, and a few new ones entering. However, e-Paper is still only widely available in monochrome formats. Clear needs are improved black/white shutters that can allow video rate and high-resolution RGBW color displays. Another clear need is non-video-rate but excellent reflective color, for which CMY approaches are rapidly taking the performance lead. After this year passes, we will again be wiser on how e-Paper stacks up commercially as e-Paper continues to grow in existing monochrome applications, while its developers seek a way to break out the technology into large-volume color e-Paper products for signage and video-speed tablets. ■

Display Week 2012 Review: 3-D

Developers forge ahead with both stereoscopic and autostereoscopic applications, with an emphasis on eye tracking.

by Steve Sechrist

3-D was a recurring theme at SID's Display Week in Boston this year, from the opening keynote address to the Best-in-Show awards, to the exhibition floor, and in the technical and business conference sessions as well. Examples of both glasses-based and autostereoscopic 3-D were presented. And if Display Week 2012 is a reliable signpost, the road to high-performance glasses-free 3-D displays will be paved by efficient eye-tracking technology.

The Eyes Track It

At Display Week's Business Conference, hosted by IMS Research, AU Optronics introduced its next-generation eye-tracking autostereoscopic technology in a presentation from Wei-Leung Liau, Associate Vice-President at AUO's Display Technology Development Center. Liau described the evolution of 3-D displays and provided an overview of conventional glasses-free 3-D technology as well as highlights from AUO's high-resolution eye-tracking technology. Stating that consumers ultimately want the burden of glasses removed from the 3-D viewing process, he characterized the major drawback of conventional lens and barrier approaches to autostereo: dead zones, ghosting images, and resolution loss as viewing zones increase.

AUO's solution has been to develop an eye-tracking technology in conjunction with a switchable lenticular lens. To get there, the company created an image algorithm chip and eye-tracking camera that shift the 3-D sweet spot to where the viewer is looking (Fig. 1). AUO showed this technology at Display Taiwan last June in a laptop prototype and I saw it again at CES 2012 in January in a Sony device. The Sony product manager confirmed the AUO source at that time, as the interface software used was unmistakable. According to AUO, the benefits of using an eye-tracking solution for autostereo include a dead-zone-free environment, high-resolution 2-D (full HD)/3-D (HD), normal frame rate, high brightness, and 2-D/3-D switchability.

The company is also planning to create a "local 3-D window" within a display. This would allow a portion of a display screen to show 3-D while the rest of the image remains in 2-D. It's a feature that was demonstrated by others at Display Week (shown at the NLT/Renesas booth in the exhibition, for example) and is aimed at advertisers who can use the application to show off product features and to call attention to specific ads.

Elsewhere on the floor, LG was showing off a 4.5-in. autostereoscopic-display prototype that used eye tracking to deliver what the company billed as a "Viewing Angle Free 3-D" image. The prototype panel came mounted inside a package housing a camera used to generate the face/eye-tracking data. LG Researcher Dongkyu Kim said the device initially was created to convince the LG team

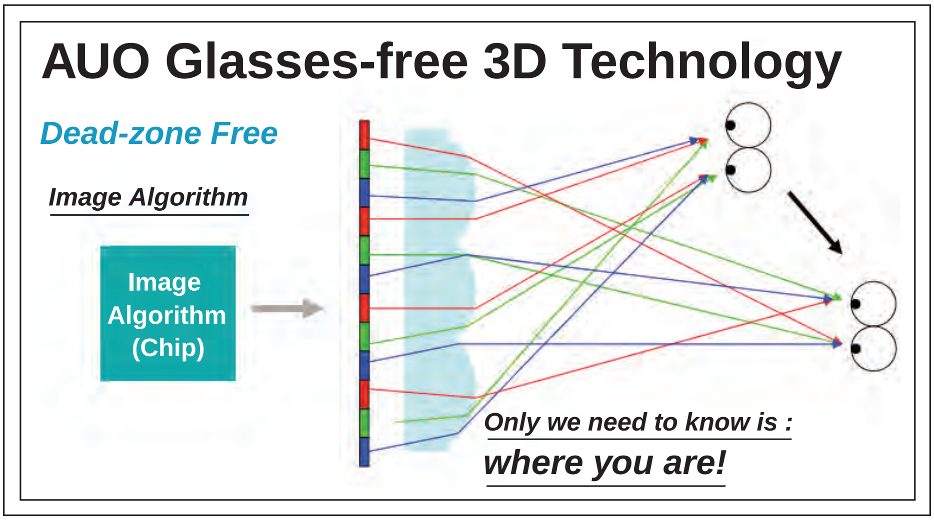

Fig. 1: AUO's popular eye-tracking technology uses an image algorithm chip in combination with a camera.

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of the viability of this approach, which will eventually be built into a next-generation 7–10-in. tablet display. Limited specs were available on the prototype, but I did learn that the horizontal and vertical viewing angles were 48° and the optimal viewing distance for this size panel was at 30–35 cm.

One of the most noticeable indicators of the importance of both 3-D and eye tracking at Display Week this year came when Dimenco received a Best-in-Show award for its "Dynamic View" technology. The company's 23-in. autostereoscopic gaming monitor switches between a single (eye tracking) or multi-user autostereo 3-D image for viewing high-resolution games, film, or TV content. (For more about this product, see the Best-in-Show article in this issue.)

There were also some notable papers from the technical sessions that featured 3-D with eye tracking or face tracking. "Hardware and Software Technologies for Glasses-Free 3-D TVs and PCs" by G. Ito from Toshiba's R&D Center outlined both hardware and software solutions for the company's portrait/landscape switchable display now in mass production. Topics included a one-dimensional integral imaging method, a new moiré-free pixel design using a vertical lenticular sheet, 2-D/3-D switching with a liquid-crystal gradient index (LC GRIN) lens (showing uses in its 3-D panels), 2-D/3-D image conversion, face tracking for 3-D viewing zone shift, and 3-D super-resolution image processing.

C. H. Yang from the Department of Photonics at National Chiao Tung University presented the late-news paper "High Resolution Time-multiplexed Backlight with Tracking System for Multi-user Applicable Wide-viewing Autostereoscopic LCD." Notable was the work done to address the commonly observed problems of limited 3-D viewing angle and fixed-position observer locations. The proposed solution was a combination of an adjustable fine-stripe (AFS) backlight, a lenticular lens, and a 120-Hz LCD with sufficient resolution to deliver a wide viewing angle for multi-user autostereoscopic applications. The trick is to use a camera for eye tracking of multiple viewers. According to author Yang, "…each strip on the AFS backlight can turn on and off individually. The function of the lenticular lens is to direct the light of different strips into the different viewpoints," as the AFS backlight is adjusted to project light to different users. Yang said since the tracking system can locate the viewer's position, the time-multiplexed display can project a temporal two-view image to each user while maintaining high resolution and increasing viewing angles for multi-users simultaneously.

Technically 3-D

The above were just two of the exciting papers presented at Display Week. In all, the technical Symposium featured no fewer than 12 3-D sessions with four papers each. These included distinguished and invited papers highlighted at the show by respective committee chairpersons for special recognition.

LG Display and Sharp pointed to the future direction of 3-D TVs in two Distinguished Papers focusing on autostereo. In "Development of Super Hi-Vision 8K x 4K Direct-View LCD for Next-Generation TV," Sharp Corporation's T. Kamakura and team described their 8K × 4K (7680 × 4320) resolution Super Hi-Vision UHD LCD offering 16× the resolution of a Full-HD system in a whopping 85-in.-diagonal display. The company said the panel has 103 ppi and a luminance of 300 cd/m^2. Other features include an aspect ratio of 16:9, 10-bit RGB color, and 60-Hz operations. The display also uses an RGB LED backlight.

LG Display presented "Implementation of 240-Hz 55-in. Ultra-Definition LCD Driven by a-IGZO Semiconductor TFT with Copper Signal Lines." Author N. Gong said in his talk, "As the resolution and the frame rate of a panel increase, pixel charging time and panel transmittance ratio decrease." The paper shows how LG implemented a 55-in. LCD TV with 240 Hz and an impressive 3840 × 2160 resolution, using a metal-oxide (IGZO) backplane (IGZO TFT and copper metallization.) According to Gong, the group investigated three panel-driving architectures, concluding that a bus-line architecture with 1G1D (one gate one driver) works best, delivering a line time for a 240-Hz refresh rate of just 1.6 μsec from a double-bank IC connection. This approach offers the promise to deliver "… cost benefit, process competitiveness, and design flexibility," Gong said. It can also be mass-produced on existing a-Si TFT lines "… with minor modifications." This is partly due to prior development done by LG in the copper metallization process for an a-IGZO TFT. His talk also covered solutions to the problem of charge time for each pixel, reduced by half "…just by doubling the number of gate scan lines" and offered an explanation of the company's panel fabrication of the oxide TFT manufacturing process using an inverted-staggered bottom-gate structure. Their efforts paid off in developing a UD AMLCD panel in a 55-in. prototype that Gong concluded, "proved that a-IGZO TFT, IPS mode, and copper metallization technology is very promising for the large-sized high-resolution TVs."

"Displays Using Scanning Laser Projection" by Dr. Brian Schowengerdt *et al.* from the Department of Mechanical Engineering at the University of Washington covered advances in 3-D using several devices built from multiple scanned laser projectors. One consists of "…arrays of scanning fiber projectors [that] can enable massively multi-view autostereoscopic displays with full head-motion parallax and partial accommodation cues," Schowengerdt said. The group also developed a head-mounted display in the lab that incorporates a 1 mm × 9 mm projector that can fit within the temples of eyeglasses and "…uses a vibrating single-mode optical fiber to produce scanned images," that Schowengerdt calls "the smallest display in the world."

3-D Visions Large and Small

The 3-D developments presented at Display Week started off with a far-ranging talk and included displays of all sizes on the show floor. The event began with a visionary keynote address by Ramash Raskar of MIT Media Lab's Center for Future Storytelling, who discussed novel display developments based on work done at the Lab's Camera Culture Group as well as at Mitsubishi's (MERL) R&D lab. One of the most exciting is a "shift glass" approach that touches the very frontiers of optics. This approach involves shifting the physics (space, wavelength, time, and light) of a display; the results could eventually be applied to autostereoscopic panels. The MIT group has also developed and studied light-sensitive displays, multi-touch/gesture-driven interactive displays, and autostereoscopic 3-D displays using lenslet arrays and layered light-bending masks.

In the exhibit hall, there were lots of 3-D options for next-generation mobile devices and other small display applications. In the NLT/Renesas Electronics booth was an autostereoscopic LCD in a 3.1-in. WQVGA (400 × 240) prototype that offered six views – a lot from a relatively small (high-resolution) display. Renesas Display engineer Dale Maunu said the LCD uses an LTPS backplane and features a new "HxDP" pixel array (horizontally × times – density pixels). The panel uses a lenticular lens to accommodate the unique horizontal RGB stripe that generates the 3-D image. The module uses RGB color pixels, with three subpixels each, which are striped horizontally and split in sixths lengthwise. This delivers a resolution 6× times that of conventional (vertically striped) 3-D LCD panels. NLT's HxDP technology is an outgrowth of the HDDP (horizontally double-density pixels) technology originally used in the company's multi-view displays (Fig. 2).

Chimei Innolux (CMI) was showing a 4.3-in. LCD panel with switchable barrier technology delivering an autostereoscopic image that channels light through a cell-gap pixel structure. In the on-state it generates a left-eye/right-eye image for on-axis viewing, but delivers simultaneously a decent 2-D image for any off-axis viewing. In the off-mode, a standard (higher resolution) 2D view is created that solves the problem of one-viewer-only images, particularly on larger mobile displays such as tablets. The group claims its novel approach delivers a wide 3-D viewing angle, low 3-D crosstalk, and low 3-D moiré. There are other multi-mode 3-D systems that seek to serve specific user needs (Dimenco for one), but CMI is delivering its product without the use of eye tracking, which could possibly prove to have advantages in cost, processing, and power savings – all key issues in mobile applications (Fig. 3).

Another attention getter in the Dimenco booth (besides the Best-in-Show winner) was a 56-in. 4K × 2K 3-D TV offering 28-view autostereo with adopted Dolby 3-D technology. Dimenco said the Dolby implementation was part of a combined project between Dolby Labs and Royal Philips Electronics, using the Dolby 3-D HD technology suite. The company also showed a 55-in. tiled 3-D video wall, using a narrow-bezel display that is designed to target digital signage and other large installation applications.

There were two other displays on the show floor that were offering 3-D options with glasses that could hardly be missed: Samsung's 55-in. AMOLED TV with RGB OLEDs and LTPS backplane and Smart Dual-View feature and LG Display's 55-in. AMOLED TV with white OLEDs and the oxide backplane in a thin form factor. Both won Best-in-Show awards.

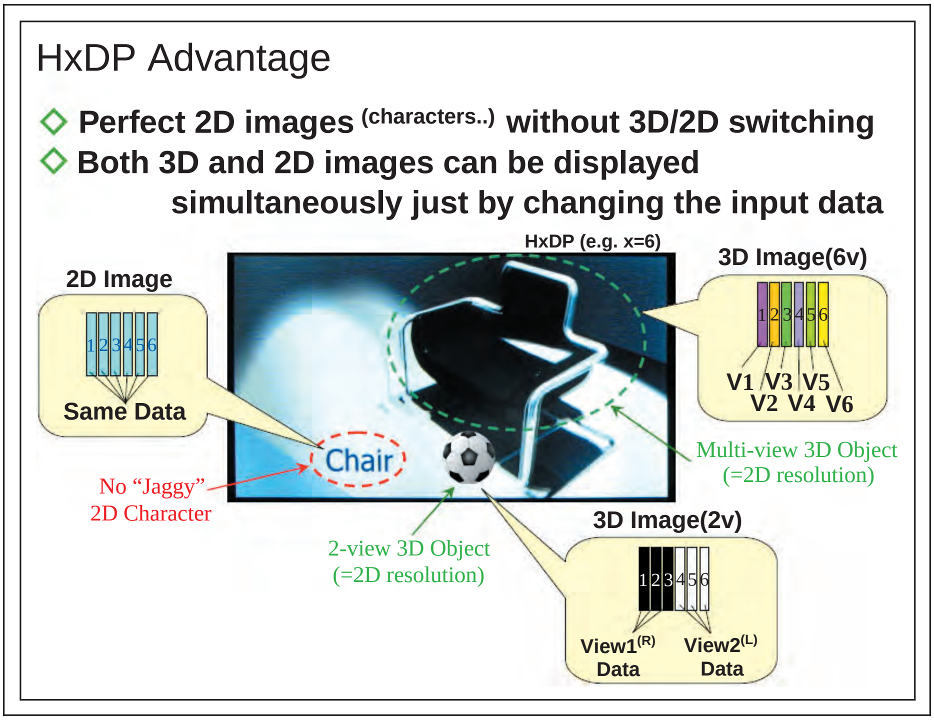

Fig. 2: HxDP is shown in three operation modes. Source: NLT.

Samsung's 55-in. AMOLED TV has been written about in the OLED Technology Review in this issue, but I wanted to note that the AMOLED display was one of the brightest on the show floor and emitted a highly saturated (almost too saturated) color image. While in 3-D, the image looked spectacular, perhaps because it may have toned down the (oversaturated) colors when the display was shown in 2-D.

A particularly interesting aspect of the new display was how Samsung took the concept of 3-D delivery to new heights with its Smart Dual-View feature that uses the active 3-D technology on its new OLED TVs for simultaneous dual viewing. By applying the left-eye/right-eye glasses approach, the company created a technology that allows two com-

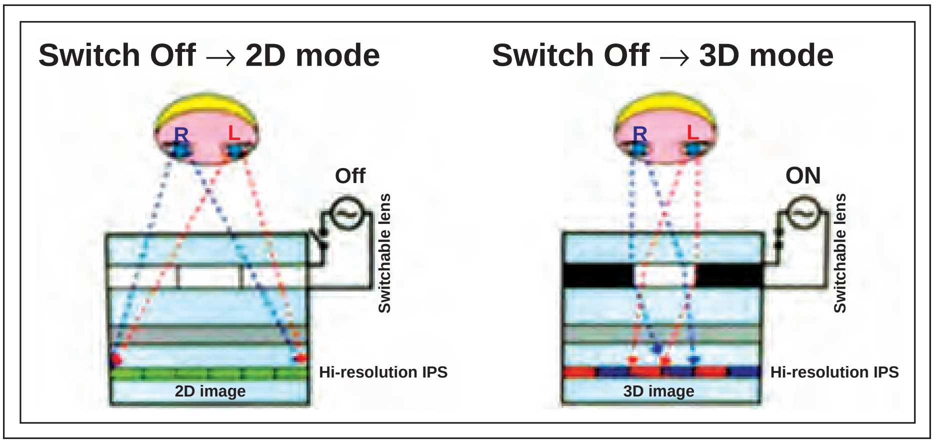

Fig. 3: CMI's barrier approach switches between 2-D and 3-D. Source: Author/CMI.

pletely different Full HD programs to be viewed on the same set, at the same time.

Samsung also debuted new active 3-D glasses designs that remove weight and bulk from the wearer's face, moving most of its discrete electronics to the "arms" of the glasses that rest on the ears. The result is a well-balanced feather-like feel, which goes a long way toward making active glasses more acceptable.

LG was also on hand with a 55-in. AMOLED TV based on WRGB OLEDs with an IGZO (metal-oxide active-matrix) backplane. The company claims this combination of using white OLEDs and color filter together with the metal-oxide backplane should give it a manufacturing price advantage over alternative approaches (this is a reference to the Samsung LTPS backplane methodology). LG uses a passive 3-D technology with a film-patterned retarder and low-cost glasses. The company is planning mass production this year, and as mentioned earlier, took home a Best-in-Show award, as did Samsung. For more on these two units, also see this issue's Best-in-Show article.

The Future of 3-D

Most experts agree that the bottom line to delivering autostereo in the near term will depend on higher-resolution and faster-addressing displays and perhaps will include some form of eye-tracking technology. As evidenced at Display Week, we can look forward to continued progress in these areas, as developers push the display technology envelope, edging us ever closer to autostereoscopic display nirvana. Suffice it to say the best and brightest in the category were on their game at Display Week in Boston, and it's a solid bet that a future glimpse of mainstream 3-D display technology could already be touched and more importantly viewed at the ground-breaking event. ■

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Display Week 2012 Review: LCDs

Despite financial setbacks, the LCD industry continues to innovate.

by Alfred Poor

FROM ovens to cars, from mobile phones to tablet computers, from dynamic store signage to high-definition televisions, the dominant information-display technology clearly continues to be liquid crystal. Display Week 2012 reflected the leading role of LCDs in the industry; from the 10 sessions in the symposium (more than any other track) to the exhibit hall, the technology was visible at every turn.

Traveling a Bumpy Road

Participants of this mature technology are not coasting along on autopilot; they face some daunting challenges. One of the most significant was presented from the start at the Business Conference hosted by IMS Research the day before the exhibition opened. Several speakers made reference to the fact that LCD suppliers on the whole have lost money for the prior consecutive seven quarters. Stiff competition has forced them to find ways to reduce material and production costs; profit margins have been difficult to maintain.

The industry is also facing competition from new technologies on a scale that has not been seen since flat panels started to replace CRTs in many applications. OLEDs are clearly a major challenger; two 55-in. HDTV demonstrations in the exhibit hall drew admiring crowds throughout the week, and OLED technology already has made significant inroads in the mobile-device market. Various forms of bistable displays are succeeding through e-Readers and other applications.

Even the success of LCD technology has created challenges for the industry. For the first time ever, the LCD-TV market declined in the first part of 2012, as penetration rates in North America and Western Europe are around 90% (as reported by IHS). This has resulted in questions about how to make the best use of the production capacity already in place.

The LCD industry is not just sitting back as a spectator and watching all this develop. Researchers and manufacturers are pushing hard to advance the technology to lower costs even further and to improve performance. For example, the symposium had three separate sessions devoted solely to the discussion of blue-phase liquid crystals (BPLCs), including a paper from Hui Chuan Cheng *et al.* from the University of Central Florida about a polymer-stabilized BPLC that uses vertical field switching and an oblique path for the backlight.

Will Rust Replace Sand?

Another hot topic was about the use of metal oxides instead of silicon as the semiconductor backplane for LCD panels. Some of this research has been driven by the fact that OLEDs need better electron mobility in their

Fig. 1: Sharp demonstrated a 32-in. LCD that uses IGZO for its semiconductor backplane. One measure of the metal-oxide capabilities is that this panel has QHD resolution (3840 × 2160 pixels). Photo courtesy the author.

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backplanes, but a rising tide raises all boats and the benefits can also help LCDs.

At present, more than 95% of LCDs use amorphous silicon (a-Si) for their backplanes. While this is good enough for most applications, the drive for higher pixel densities has increased the use of laser-annealed polysilicon (poly-Si) backplanes. There are limits to the size of the panels that can undergo laser annealing efficiently, and this resulted in a search for alternatives. A leading alternative is the use of metal oxides, and IGZO (In:Ga:Zn oxide) is one of the most popular choices at this point.

At Display Week, Sharp and Semiconductor Energy Laboratory announced that they have used IGZO to create mobile LCD panels with a resolution of 500 pixels per inch (ppi). Sharp Microelectronics of the Americas (SMA) also introduced a 31.5-in.-diagonal LCD with QFHD resolution (3840 × 2160 pixels), which is equivalent to four 1080p displays (Fig. 1).

Quantum Solutions

LCDs have also moved away from cold-cathode fluorescent lamps (CCFLs) for backlights and most are now using solid-state LEDs as a light source. Expense and color performance are two of the challenges presented by LED backlights, and a new joint effort by 3M and Nanosys has provided an alternative. Nanosys's Quantum-Dot Enhanced Film (QDEF) can transform blue light into precise frequencies of red or green light. When stimulated by a blue light source, the film emits white light suitable for an LCD backlight. 3M provides a polymer/inorganic barrier film to shield the QDEF from damaging oxidation.

By adding this film to an LCD panel, manufacturers can switch from expensive white LEDs to blue LEDs. This also eliminates the problem of "binning" the white LEDs to get the desired color temperature, an elimination that may result in a cost reduction of 25–50% in the cost of the LEDs, according to a 3M representative. The Nanosys QDEF was the recipient of SID's Display Component of the Year Gold Award.

The Large and the Small of It

Among the large LCDs in evidence at Display Week, one of the most impressive was a 55-in. QFHD LCD that is also an autostereoscopic 3-D display (no glasses required) from AU Optronics Corp. This unit is commercially available, and it won SID's Display of the Year Gold Award.

Sharp also announced an impressive 80-in. LCD panel to go along with its 60- and 70-in. models, all intended for digital-signage applications. (After all, what fun is it having a Gen 10 LCD fab if it is not going to be used to make really big panels?)

At the other end of the logarithmic scale, one could also see some tiny LCD panels. For example, Kopin Corp. showed a full-color VGA LCD (640 × 480 pixels) that was a mere 0.21 in. on the diagonal (Fig. 2).

The company also showed a WQVGA (480 × 240 pixels) designed for "information snacking" applications such as augmented reality. The device can produce images with a luminance of 1000 cd/m^2 while consuming less than 150 mW of power. In the same booth, Forth Dimension Displays showed a new QXGA (2048 × 1536 pixel) liquid-crystal–on–silicon (LCoS) microdisplay. Lumus was also showing an LCOS panel with 720p resolution on a 0.38-in.-diagonal display intended for near-to-eye applications, such as head-mounted displays embedded in eyeglasses. The see-through image would make it well-suited for augmented-reality systems such as the Google Project Glass.

Taking "small" in another direction, LG Display demonstrated a 4.5-in. LCD panel that was a mere 0.99 mm thick. The company's Ultra Slim technology reduces the backlight-unit thickness to just over half the normal dimension. When paired with thinner glass, the LCD panel could easily be mistaken

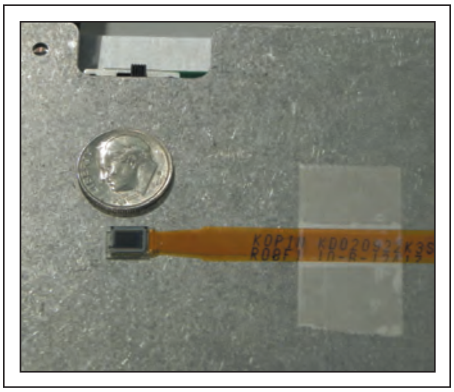

Fig. 2: Kopin's VGA microdisplay is just 0.21 in. on the diagonal and is designed for near-to-eye applications such as viewfinders. Photo courtesy the author.

Fig. 3: LG Display showed a video wall using nine 55-in. 3-D LCD panels that are separated by only 5.3 mm, the combined width of their thin bezels. Photo courtesy the author.

for an OLED panel if just taking the thickness of the panel into consideration.

An LCD for Every Purpose

Between these extremes, one could find just about anything else one might want in a display at the exhibition. Two of the industry leaders had a large presence in the hall. LG had a variety of panels on display, including a 55-in. model with a bezel width of only 5.3 mm between tiled panels (Fig. 3). These tiles support stereoscopic 3-D with passive glasses, making it practical to create large 3-D video walls.

Samsung showed a 13.3-in. panel (1366 × 768 pixels) that was only 2.85 mm thick, available now as a high-definition display for ultrabook computers (Fig. 4).

The recently created Kaohsiung Opto-Electronics (KOE), formerly Hitachi Displays, was showing in-plane-switching (IPS) panels in conjunction with Ocular LCD's touch-panel technology. Chimei Innolux Corp. (CMI) demonstrated its MQ technology that reduces motion blur in mobile-device displays by using a combination of overdrive and a flashing backlight. Tianma Microelectronics was another LCD manufacturer that showed a variety of LCD-panel products in its booth including a 4.5-in. LCD for mobile devices that uses NLT's Super-Fine TFT (SFT) technology to obtain QHD (960 × 540 pixel) resolution on the small panel.

Kyocera (formerly Optrex) demonstrated a wide range of LCD panels intended for automotive and industrial applications, including a 2.5-in. round display and panels using its Omni Directional View (ODV) technology that improves viewing angles. Renesas/NLT Technologies showed a 21.3-in. 5.8-Mpixel monochrome LCD designed for medical-imaging applications and a 9-in. color 1080p panel suitable for automotive entertainment.

Several exhibitors, including Kristel Displays and LiteMax, were showing high-brightness LCD panels for a range of applications. And if one could not find an LCD panel size needed for a specific application, Tannas Electronics Display was on hand showing its custom panel-cutting technology that can provide just about any dimension that might be required.

Sailing through the Storm

The LCD industry may be navigating some stormy fiscal seas at the moment, but it remains the pre-eminent technology for displays of all sorts. Expect to see LCD panels get thinner and lighter, which is likely to yield benefits to mobile devices such as smart phones, tablets, and ultrabook computers. If IGZO is the success that the manufacturers hope it will be, we could see resolutions increase and production costs fall even further. These and other improvements may help LCD hold off the growing attack by OLEDs for market dominance. And if Display Week 2012 is any measure of the future for these versatile flat panels, it appears that research is ready to help manufacturers advance to the next level and compete with new technologies as they come along. ■

Fig. 4: Samsung's 13.3-in. WXGA notebook panel is claimed to be the thinnest LCD notebook panel on the market. Photo courtesy the author.

Part I: A Brief History of Key Areas in Display Technology

In Part I of our 50-Year Anniversary Special Coverage, display-industry experts outline the history of displays through parallel technology developments.

FOR this special 50th anniversary article, *Information Display* asked six display-industry experts to share their knowledge and perspective of specific areas of display technology: cathode-ray tubes (CRTs), projection, early roots of liquid-crystal displays (LCDs), active-matrix LCDs (AMLCDs), plasma display panels (PDPs), and organic light-emitting-diodes (OLEDs). Some of the technologies – CRTs, for example – were once dominant but have since been eclipsed by others. However, something that becomes clear from reading these entries is that no one technology succeeds completely independently of another. For example, without knowledge gained from designing CRTs, developers would have had a much harder time creating, or even imagining, today's LCDs. Backplane advances that enabled better LCDs have now helped realize larger OLED displays as well. Today's technology will, in turn, bolster the displays of the future – displays we can only guess at today. We hope you enjoy the following stories, told from the standpoint of industry veterans who experienced these technology shifts firsthand.

CRT Retrospective

Not so long ago, to speak of a display was to speak of a CRT. The industry owes a tremendous debt to the developers and manufacturers of CRTs.

by Chris Curtin

Reviewing the cathode-ray tube (CRT) as part of SID's 50th anniversary takes one on a bittersweet journey. Initially, and for a large segment of the past 50 years, the CRT was the major topic at SID meetings and the only display device in TV factories around the world. By 2012, the CRT has become a footnote in the realm of display device development.

***Chris Curtin** has worked on CRT design and manufacturing since 1963. Beginning in 1989, he helped develop the field-emission display until retiring in 2001. He can be reached at ccurtin@rockisland.com.*

The evolution of the color CRT for TV receivers ranks as the most significant impact of this technology in the last 50 years. By the early 1960s, the three-beam shadow-mask design was the foundation for continual increases in screen size, color purity, resolution, luminance, and cost reduction to satisfy consumer requirements. Most significant of the system-engineering improvements was the increase in luminance over a 20-year period as shown in Fig. 1.

While not of the same magnitude improvement, the scaling up of the color-CRT screen size to 36 in. and beyond in the 1990s represents a major advance in glass faceplate and bulb design as well as electron gun, magnetic deflection yoke, and shadow-mask/grid design.

The developments for color-TV viewing provided the foundation for higher-resolution CRTs required for computer graphics and computer-aided design. In the early 1980s, the price of solid-state memory (RAM) decreased to the point where computer-based workstations using color CRTs became common. As costs were reduced further, the personal computer evolved from monochrome to color CRTs, initially at 13 in. on the diagonal and eventually to 19–25 in. on the diagonal. The CRT's color purity and ability to match the output of color printers set standards for flat panels as they began to replace CRTs in workstations and PCs in the 1990s.

Major CRT developments were also made for oscilloscopes, medical imaging, radar, avionic cockpits, and large-screen projection systems. As the electronics industry boomed during the 1960s, electrostatically deflected CRTs for oscilloscopes helped lead the way with ever faster response times, culminating with the addition of a micro-channel-plate multiplier to allow photography of single-shot

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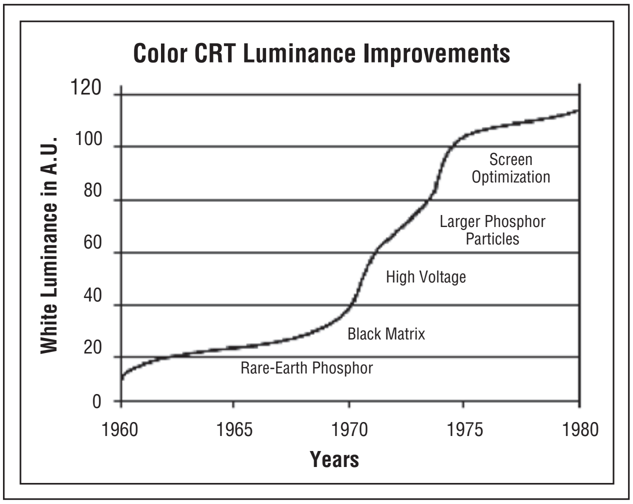

Fig. 1: Color CRT luminance increased dramatically over the period between 1960 and 1980. Source: SID 50-year history committee timeline (CRTs), www.sid.org.

signals moving at the speed of light. Before the era of solid-state memory, storage CRTs served to capture and display transient events. An important spinoff using the phosphor-storage technology was the high-resolution monochrome graphic computer terminal in 11-, 19-, or 25-in. models, which dominated the field until the price of solid-state memory dropped to a competitive point in the 1980s.

Hardcopies of the graphic display were obtained via a fiber-optic line-scanned CRT exposing dry silver paper.

High-resolution electron guns developed for computer graphics enabled specialized monochrome CRTs for medical-imaging applications such as digital radiography, ultrasound, and nuclear medicine. The avionic "glass cockpit" required extremely high brightness to overcome the sunlight that often shone on the display screen. High-current electron guns and high voltage on the phosphor screen along with a rugged shadow-mask design combined to satisfy this need.

Projection CRTs had dual roles, one for large-screen TV and another for flight simulators and control rooms. While the sales volumes were modest compared to the shadow-mask color CRT, this was the major route to large-screen displays in the last century. Typically using three small monochrome CRTs (red, green, and blue), very high intensity was needed to achieve adequate luminance at the final screen. Light valves that separate the addressing function (the "valve") from the light-generation function (light bulb or LED or laser) eventually replaced CRTs as the "projection engine" by offering more performance at a comparable price.

(More details, including some of the companies involved, appear on the "CRT timeline," which can be found, along with timelines for plasma, projection, LCD, AMLCD, and OLED, at www.sid.org. These advances required literally thousands of scientists, engineers, and technicians around the world, some of whom were formally recognized by the SID and are included in the timeline.)

Major developments in literally hundreds of electron-beam devices or technologies were completed during the last 50 years. In the end, the bulk and size limitations dictated by the mechanical requirement to support the atmospheric pressure limited the traditional CRT's application and markets. Long viewed as the "ultimate goal," flat and thin CRTs saw significant development in the 1990s using a screen-sized matrix array of cold-cathode field emitters. However, the improving performance and decreasing costs of LCDs ended the CRT's competitive threat at the beginning of this century.

A Look Back at Projection

Pico-projectors and micro-projectors will outpace, but not replace, mainstream projectors within the next few years.

by Matt Brennesholtz

Projection Before SID

From 1902, until before the Society for Information Display was founded in 1962, electronic-display technology was dominated by the cathode-ray tube (CRT). The first CRT television sets, both direct-view and projection, were available before World War II.

***Matt Brennesholtz** is an analyst at Insight Media. He can be reached at matthew@insightmedia.info.*

The war largely put an end to consumer use of TVs but also led to rapid changes and improvements in CRT technology. For example, radar systems developed during the war played a major part in the Battle of Britain and required CRT displays for their operation.

Following the war, there was a resurgence in television and projection technology for entertainment use. Perhaps the ultimate expression of the large-screen CRT projector was an RCA tri-color receiver-projector developed by Dr. David Epstein, which provided theater-sized screen images. This behemoth was built in 1951 to demonstrate NTSC color-TV signals in a theatrical environment.

The CRT was not the only available display technology suited for projection, however. The Scophony projector from the 1930s was a surprisingly modern, mechanically scanned projection system based on rotating drum mirrors, an arc lamp, and an acousto-optic modulator. Scophony systems were used in a few movie theaters for live events, but plans to build a home version of this projector died when the war started.

Oil-film light-valve projection had its origin in the prototype system built at the Swiss Federal Institute of Technology in Zurich and was demonstrated on New Year's Eve in 1943. This technology eventually grew into the Eidophor projection system, which became a commercial product in 1958. A competitive oil-film system from General Electric, the Talaria, was also introduced in 1958. (Augustine Albanese from GE presented a paper on this system titled "The Light-Valve Projection System" at the initial SID technical meeting in 1963.) These systems were capable of producing much higher light outputs than CRT projectors and dominated the high end of the projector market until they were replaced by LCD-based projectors in the early 1990s. The Talaria finally went out of production in 1994 and the Eidophor in 1997.

The Early SID Years: CRTs and Light Valves (1962–1992)

SID was founded in 1962 and held its first two technical meetings in March and October 1963 in California and New York, respectively. Projection was a part of the Society right from the start. In the March meeting, 4 of the 13 technical papers presented were directly related to projection, including one given by the current SID historian, Pete Baron. In the October meeting, 3 of the 15 presented papers were on projection topics, including one on laser projection. Overall, for these first two SID meetings, 25% of the technical papers were projection related.

Early in these years, interest in large-screen CRT projection was low because of the superior performance of oil-film light valves. During this period, the CRT projector was mostly limited to professional applications where the screens were not large enough to justify the use of a light-valve projector.

The lull in consumer CRT projectors ended in 1972 with the introduction of the Advent VideoBeam projector with Schmidt optics, developed by Henry Kloss from a design by Art Tucker. Liquid-crystal light valves (LCLVs), also known as light amplifiers, began to compete with oil-film light valves for the large-screen market in 1972, with the development of a LCLV projector by Hughes for the U.S. Navy. Early units had slow response times, but by 1977 Hughes had developed a three-light-valve system suitable for showing color television images. This LCLV technology eventually developed into what is known as liquid crystal on silicon (LCoS) today.

Toward the end of this period, a number of companies, including Sharp, Barco, and Seiko Epson, introduced projectors based on liquid-crystal devices. These LCD projectors had marginal performance in terms of resolution, light output, and contrast, even compared to the standards of the time. But they were more portable than either the CRT or light-valve projectors of the time and they presaged the coming revolution in projection technology.

Microdisplay Projection (1992–2012)

Two events, one in 1992 and the other in 1993, doomed CRT and light-valve projection. First, in 1992, Barco introduced the BarcoData 5000 projector, popularly known as the "Light Cannon." This was the first LCD projector that had performance comparable to light-valve projectors. It was large and expensive to buy and operate but not as large nor as expensive as oil-film or LCLV systems with comparable performance. Oil-film systems have vanished from the projection landscape, but LCLV technology survives as LCoS. The BarcoData projector could hardly be called a microdisplay projector, however, with its 5.8-in. panels.

The étendue issue, or the relative size of the light source and the projection microdisplay, was essentially solved by Philips in 1993 with the introduction of the UHP lamp. This lamp had a mercury fill and produced light from a very small volume of space, with an arc length not much more than 1 mm long. The UHP also had a very high efficacy and long life, compared to other short arc lamps in use such as xenon. This small arc size enabled an explosion of microdisplay-based projectors that used LCD, DMD, or LCoS technology.

Another important 1993 milestone was the demonstration of a 768×576 color-sequential digital micromirror device (DMD) by Texas Instruments. The DMD was so popular that the 1994 SID symposium devoted an entire session to it. The first commercial DMD-based color-sequential projector was introduced by Barco in 1996.

Texas Instruments and Hughes/JVC began the digital-cinema revolution in 1999 with the first digital-cinema projectors, such as the unit shown in Fig. 2.

Projection into the Future (2012 to ?)

The display industry has grown, to put it mildly, and the most recent SID Symposium in Boston drew 426 technical papers, about 24 of which directly related to projection technology for a total of 6% of the papers, down from 25% during the 1963 high point. This does not necessarily mean that projection technology is on the wane; it is just an indication of the rising importance of direct-view display technologies. For example, when the Society was founded in 1962, telephones did not have displays. Now, roughly 1.7 billion cell-phone handsets will be sold in 2012 and every one of those handsets has at least one display.

Fig. 2: *This DLP projector used in 1999 digital-cinema tests was mounted on a Christie xenon-lamp lighthouse and was originally designed for a film projector.*

Projection technology has always been about large-screen images, which, in 1962, meant images larger than about 21 in. Today, mainstream electronic projection technology is rarely used for images smaller than about 60 in. Direct-view plasma or LCDs up to about 150 in. on the diagonal are available, if not affordable. Still larger direct-view displays in sizes limited only by your budget are available using LED arrays. These displays can easily show an instant replay of a football goal to 100,000 screaming fans in a stadium.

When given a choice between projection and direct view, most end users select a direct-view display unless the price differential is too high or there is some other reason why a direct-view display is unsuitable. This has given rise to a market for small pico-projectors and micro-projectors suited for making images in the 20–60-in. range.

Fig 3: This NEC NP-PA500U 5000-lm installation projector is for larger conference rooms and auditoriums. This projector is based on three 0.76-in. LCD microdisplays, each with a resolution of 1920 × 1200 pixels. At $5899, this projector costs about 10% of what a 1992 1000-lm, lower-resolution Talaria oil-film projector cost.

Why would anyone want a 20-in. projected image when a 20-in. computer monitor can be purchased from a respected brand for $100? The answer here is convenience – a 20-in. monitor and its power supply cannot fit into your pocket. A pico-projector that generates a 20-in. image will not only fit into your pocket but within a year or so it will fit inside a cell phone. If the 4-in. display in a handset or the 10-in. display in a tablet just is not big enough, a pico-projector will provide a larger image, certainly 20 in. and maybe larger, depending on the ambient light.

By unit volume, forecasts indicate pico-projectors and micro-projectors will outrun mainstream projectors within the next few years, but mainstream projectors are not going away. The fastest growing market for mainstream projectors in the 2000–5000-lm range is education, although other professional AV markets remain strong as well. An example of a modern professional AV projector is shown in Fig. 3.

Electronic projection technology has evolved since it was first demonstrated in 1902 with a 12.5-line scanned image and since SID was founded in 1962. Near-term and "distant future" goals for projection displays were given by Anthony Rugari in his 1963 paper titled "Laser Display Techniques," as shown in Fig. 4. Clearly, we are already well beyond the "Distant Future," at least in terms of projection displays.

The need for large, bright, high-resolution, affordable images has not gone away even though the market definitions of "large," "bright," "high-resolution," and "affordable" have changed since SID was founded. Therefore, projection displays have not gone away nor are they expected to go away in the foreseeable future.

	Near Future	Distant Future
Resolution	one million elements	four million elements
Highlight brightness	50 fL	100 fL
Contrast ratio	10:1 in dark	100:1 in dark
Screen size	10 ft x 10 ft	20 ft x 20 ft
Color	one color with five distinct shades of the color	7 colors: white, red, green, blue, magenta, cyan, yellow
Update time	30 frames/sec	30 frames/sec

Fig. 4: Shown are near-future and distant-future goals for projection displays from about the time that SID was founded. Source: A. D. Rugari, Laser Displays Techniques, Society for Information Display (October, 1963).

Further Reading

Large parts of this article are based on the paper the author published in the *Journal of the SID* in October, 2007. This article was reprinted in two parts in *Information Display* in the May and September 2008 issues. The Projection Time Line, originally developed in 2010 and available at www.sid.org, was updated in 2012 and re-issued in honor of SID's 50th anniversary.

Evolution of the LCD in the UK

The contribution of UK researchers to the development of LCDs have been substantial and fundamental.

by Peter Raynes

The UK has an enviable reputation for its contributions to the development of liquid-crystal displays (LCDs) and the pre-eminent position they now hold as the display of choice for most office and consumer-electronics equipment. These contributions have been remarkably interdisciplinary, ranging through mathematics, physics, chemistry, and engineering.

The first major contribution to emanate from the UK was the first-ever patent for an LCD, written by B. Levin and N. Levin, and granted in 1936 to the Marconi company. The next major contributions, from academia,

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were made after some 20 years had elapsed and laid out the continuum theory of nematic liquid crystals. The static theory was developed by Sir Charles Frank in 1958, and in 1968 Frank Leslie transformed it into the dynamic theory. The continuum theory is the bedrock of the vast amount of numerical modeling of LCDs employed by the industry in the development and optimization of the vast array of LCD modes currently available.

There then followed approximately two decades of discoveries and inventions from within a consortium of academia, industry, and government laboratories, which attacked the many challenges of the early simple LCD technology and laid the foundations for the multibillion-dollar industry of today. This consortium was formed and guided by three wise and determined individuals: Cyril Hilsum at the Royal Signals and Radar Establishment, George Gray at Hull University, and Ben Sturgeon at BDH Chemicals.

The early liquid-crystal materials were unstable, colored, and quite unsuitable for use in displays. In 1972, this changed dramatically when cyanobiphenyls were invented at Hull University. These stable, colorless materials had excellent device properties and, once they had been formulated into wide-temperature-range mixtures, they quickly became the material of choice of the LCD industry. Supplemented by the later addition of mixtures tailored for multiplexed displays, the cyanobiphenyls held dominance in the industry for more than a decade and resulted in two Queen's Awards for Industry to the groups involved.

Two improvements of the basic twisted-nematic (TN) device quickly followed from the consortium. The detailed optics of the device was understood and an equation derived that allowed the design of LC materials for thinner and superior TN devices. Secondly, early TN devices showed non-uniform contrast quite unacceptable to the consumer. The origins were traced to degeneracies in the liquid-crystal alignment and techniques found to remove them. These techniques and the design of materials for the superior thin devices became industry standards still in use today.

Toward the end of the consortium, two breakthroughs occurred that were key to the transformation of LCDs into the high-information-content displays so familiar today in mobile phones, computers, and televisions. It had become increasingly obvious to all concerned that the electrode sharing technique known as multiplexing did not work at all well for liquid crystals, and the prospects for using LCDs in phones, computers, and televisions looked rather dim. The reason for this difficulty lay in the response of liquid crystals to electric fields; they respond to the root mean square of an applied field, making multiplexing and high-information-content displays virtually impossible. Within a short space of time, two quite different ways forward were opened up and transformed the industry. The increase of the twist angle of the TN device produced a device with such a steep response that multiplexing became possible; this device attracted the name supertwist, or STN device. Secondly, the long-held view that electrical driving elements should be used to individually switch each pixel suddenly became a practical reality with the development of amorphous-silicon thin-film transistors (a-Si TFTs) at Dundee University. Although Dundee lay outside the consortium, the key development arose as input from within the consortium. At Dundee, Walter Spear and Peter LeComber had been developing a-Si material technology, but thought the application applied to solar cells. The consortium thought differently, and encouraged and financed the fabrication and testing of the world's first a-Si TFT-LCD array. Both technologies are still in use by the LCD industry; but the early dominance of the STN, which was easy to fabricate with existing technology and launched many new applications, was soon replaced in many of these by the superior, but much more difficult to manufacture, a-Si TFT technology.

Numerous developments subsequent to the consortium emanated from the UK. Chemists at Hull synthesised new LC materials, which became used in the ever-diversifying range of LCDs. The use of the difluorophenyl ring in difluoroterphenyls and other materials has become widespread in LC mixtures designed for one of the LCD modes in widespread use in televisions, the vertically aligned nematic, or VAN display, and its derivatives. Optical compensation films are universal additions to improve the optical performance of LCDs. Many optical compensation films incorporate materials that are derivatives of triphenylene discotic compounds with a negative optical birefringence. Ferroelectric LCDs, once seen as the great hope for high-information-content displays before the inevitable march of a-Si TFTs, owe much to UK development. The chemists synthesised new FLC materials and physicists developed an understanding of the devices and found ways of overcoming some key fabrication and driving issues. Recently, there has been a resurgence in niche applications of FLCDs, such as projectors, SLMs, and cameras.

Bistable displays, which maintain an image long after the removal of driving signals, had for some time been a goal of the LCD industry, and many options had been considered and rejected. Device physicists at RSRE, which by now had become DERA, and later QinetiQ, came up with a novel device configuration and switching mechanism known as the Zenithal Bistable Display, or ZBD. This device is truly bistable with a very attractive appearance; it is being tested for supermarket shelf labels and has yet to reach its full potential. (See the article "Approaching the "Zenith": Bistable LCDs in a Retail Environment" in the March 2009 issue of *Information Display*.)

Over the years, the UK output of key contributions has been recognized by numerous SID awards. The lists of winners of the Karl Ferdinand Braun and Jan Rajchman Prizes, the Special Recognition Awards and SID Fellows, and Senior Members contain many UK names, demonstrating the international recognition of the many contributions made by UK researchers to LCD technology.

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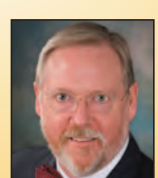
ADVANCE CONFERENCE AGENDA

Evolution of SID and the LCD
Lawrence E. Tannas, Jr., President,
Tannas Electronics

OLED Technology and Applications
(tentative)
Prof. Ching Tang
University of Rochester
(Inventor of the OLED)

Gallium Nitride Blue LEDs and Its Application in LCDs
(tentative)
Prof. Shuji Nakamura
University of Santa Barbara
(Inventor of GaN LEDs)



Glow and Grow: The Next 50 Years
David Barnes
Principal, BizWitz

Future Displays: High-Resolution AMOLED Displays
(tentative)
Prof. Ho-Kyoon Chung
Sungkyunkwan University
(former Chief of the OLED R&D Center of Samsung SDI)

Next-Wave LCDs
Prof. Shin-Tson Wu
University of Central Florida

Agenda – September 29, 2012

8:00 – 9:00 am
Check–in and Continental Breakfast

9:00 – 9:40 am
Speaker 1

9:40 – 10:20 am
Speaker 2

10:20 – 10:50 am
Break

10:50 – 11:30 am
Speaker 3

11:30 – 12:10 pm
Speaker 4

12:10 – 2:00 pm
Lunch & Networking

2:00 – 2:40 pm
Speaker 5

2:40 – 3:20 pm
Speaker 6

3:20 – 4:00 pm
Break & Networking

5:00 – 6:00 pm
Ceremony / Plaque Presentation
Chair – Erv Ulbrich

6:00 – 6:30 pm
SID President's Reception and Photo Session

6:30 – 8:00 pm
Banquet Dinner with Presentation from SID President

SID was founded in Room 3400, Boelter Hall, UCLA, on September 29, 1962, by Dr. H. R. Luxenberg. A special event that evening will include the presentation of a plaque marking the exact location where SID began 50 years ago.

Registration

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Advance Registration Fees: Before September 3, 2012.
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50th Anniversary Celebration Chair: Lawrence E. Tannas Jr., l.tannas@tannas.com

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Active Matrix and the Evolution of LCDs

Active-matrix technology has played a crucial role in the commercial success of LCDs.

by Lawrence E. Tannas, Jr.

At the time of the founding of SID in 1962, the display industry was about to embark on a paradigm shift. In the beginning, electronic displays such as galvanometers and CRTs were analog indicating transducers. Today, electronic displays such as plasma panels and LCDs are digital-matrix arrays of randomly addressable pixels. The year 1992 can be considered the mid-point in the process by which AMLCDs replaced CRTs as the primary electronic information display. One key event occurred at the Japan Electronics Show in 1988. Both Sharp and DTI (a consortium formed by 50% Toshiba and 50% IBM) predicted the future with their display of 14-in. AMLCDs in full color, using amorphous-silicon as the active-matrix element. Japan had become the leader in electronic displays – a transition that was obvious at SID's 25th anniversary.

Sharp's speculative venture to build the first Gen 1 AMLCD factory in 1992 was electrifying. Most industrial leaders conceded that the technology was feasible but believed the cost would be prohibitive. It was unimaginable then that one could manufacture a half-million transistors on a single substrate with very high yield. These days, Sharp is operating a Gen 10 AMLCD factory with 3 million transistors per substrate.

Matrix Addressing

The history of the evolution of LCDs as flat-panel displays was paced by the evolution of active-matrix addressing using active elements at each pixel. This combined embodiment is referred to as the ubiquitous active-matrix liquid-crystal display (AMLCD). A TV image is easily implemented on a CRT because the image is created by scanning an electron beam left to right, top to bottom, using passive analog techniques. At any one point on the screen, the image is only active for a very small fraction of the frame time, but the image appears continuous to the user because of the combination of the very bright persistence of the phosphor and the refresh rate. This method of drawing an image on an electronic display is called scan-line addressing.

The first generation of LCD panels also used this technique, often called passive-matrix addressing, where the pixels were individually updated one at a time from the upper left of the frame, line by line from top to bottom. However, unlike CRTs, this approach resulted in displays with relatively low contrast and poor video performance, although they were an outstanding achievement at the time. It wasn't until 1986 that the first AMLCD was mass-produced for a small handheld video player when a-Si transistor technology and LCD technology were merged into the modern AMLCD. Active-matrix addressing allows the video data for each pixel to be stored at that pixel location. The pixel remains at its intended value for the entire frame time, greatly improving contrast and opening the door for fast response times and full-motion video rendering.

In 1988, Tsamu Washizuka received the IEEE Ibuka Award for Sharp's 14-in. full-color full-motion display. Photo courtesy Sharp.

Evolution of LCDs

Some of the key milestones on the timeline of LCD technology evolution can be studied further by researching these topics:

- Discovery of the Williams Domain in LC material, Sarnoff Labs, 1962
- Invention of the twisted-nematic mode of LCDs, 1971
- Evolution of mathematical modeling of LCDs
- Synthesis of cyanobiphenyl LC material in 1972
- Continuing improvement in LCD design, in-plane twist, compensating films, TFT structure, 3-D, LED backlights, backlight addressing, high-frequency refresh, over-voltage addressing, *etc.*

Observations on AMLCDs

- It took 30 years for a-Si AMLCDs to evolve and another 20 years for their performance details and production technology to be perfected; Sharp in 1990 demonstrated "TV on the Wall," and in 1992 proved the manufacturability of a-Si LCDs.
- AMLCDs required international collaboration among companies, laboratories, and people; the center of activity moved from the U.S. and Europe to Japan and, now, Korea, led by Samsung and LG.
- Competition has continued, with plasma panels initially being used for the very large display market and passive LCDs and AMOLEDs for the smaller-display market. Today, LCDs are displacing plasma panels even in sizes up to 90 in., and AMOLED displays are being positioned to challenge LCDs in 55-in. TV; AMOLED displays and LCDs are competing in the recently created market for very-high-quality small- and medium-sized displays for smartphones and tablets.

The Future

Clearly, AMLCDs are the leading technology today just as CRTs were until 1992. Active-matrix OLEDs (AMOLEDs) have now been publicly demonstrated to show superb performance at potentially a lower cost in 55-in. sizes by Samsung and LG. It's similar to the 1990s all over again. Highly skilled display engineers are split on how the future may evolve. Again, the answer rests in the techniques used in matrix addressing, and the stigma of poor life performance in OLED materials has not been eliminated. In any event, the future is bright. AMLCDs will be getting better and AMOLED displays show promise as the next generation of displays.

Lawrence E. Tannas, Jr., *is President of Tannas Electronics, a Fellow and Past-President of SID, and Chairman of the SID 50th Anniversary Celebration Committee. He can be reached at l.tannas@tannas.com.*

The First Plasma-Display Product

Today, flat-panel displays dominate our industry, but in 1962, the year SID was founded, very few flat-panel products existed, even though the desire for practical flat panels for hang-on-the-wall TV was strong. This is the brief story of the development of the first plasma-display product, which is the ancestor of all of the flat-panel TVs we have today.

by Larry Weber

As with any invention, it all started with a need. In this case it was the need for a high-quality display for computer-based education. The University of Illinois started a project in 1960 called PLATO (Programmed Logic for Automatic Teaching Operations) to conduct research on the use of computers for education.[1] It was a pioneering project on a topic that now seems obvious. It was clear to the leaders of the PLATO project that a graphics display was a necessary component for computer education. However, in those days even a simple alphanumeric computer terminal was a real luxury. The common method for man–machine interface was the teletype and the punched tape.

In 1964, the "advanced technology" PLATO 3 system used CRT-based graphics display terminals with external scan converter memory tubes originally designed for FAA radar as the bitmap storage. This was one of the few viable bitmap storage technologies of that era. Of course the semiconductor memory that we now use in our PCs and laptops had not been developed yet.

The plasma display panel was invented by Prof. Donald L. Bitzer, Prof. H. Gene Slottow, and their graduate student Robert H. Wilson in 1964 to meet the need for a full-graphics display for the PLATO system.[2] One of the key goals of this new graphics display invention was to have inherent memory so that the bulky and expensive scan-converter tube memory could be eliminated. This first single-pixel device used neon gas to generate the familiar orange glow. Fortunately, the vacuum system used to evacuate the panel had a leak that added a small amount of air to the neon. This gave the discharge a hysteresis characteristic that inventers quickly recognized would be useful to achieve their goal of inherent memory. Pure neon gas without the leak did not have this hysteresis. The practical solution for panels that did not leak was to add a fraction of a percent of nitrogen to the neon to achieve inherent memory. Today's plasma TVs use inherent memory to hold the image during the frame time. This eliminates the need for an active-matrix transistor for each pixel.

Figure 5 shows the first plasma panel with more than one pixel. This result was first published in 1966.[3] It was a major achievement since it was also the panel that demonstrated the first matrix addressability.[4] The inventors named this invention the "plasma display panel."

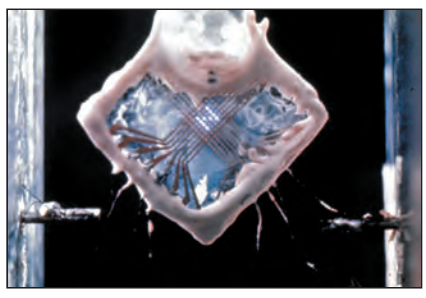

***Fig. 5:** This early 4 × 4-pixel panel was presented in the first publication on the plasma-display panel by the University of Illinois in 1966.[3] This panel was the first to have more than one pixel. It was also the first to achieve matrix addressability.[4] The outer dimensions of the panel are 1 in. square. Photo courtesy Donald Blitzer.*

***Larry Weber** started his 43-year display career as a student of the plasma display inventors and is widely considered to be the founding father of commercial plasma television. He can be reached at larryweber@ ieee.org.*

As a young graduate student, I can remember making this kind of device with the very fragile 150-µm thin sheets of glass and the vacuum epoxy that can be seen glopped around the perimeter. When I would evacuate the air from the panel, the external atmospheric pressure would usually break the thin glass. Fortunately, this could usually be repaired by applying more epoxy. Even then my devices would die after 2.5 hours due to gas contamination from leaks and I would have to periodically put in fresh gas. This was certainly not a manufacturable device.

First Product

In the next few years, a number of industrial companies continued to work toward practical products. These included Owens-Illinois, IBM, Control Data, and Fujitsu. Owens-Illinois won the race in 1971 by delivering the first practical product, which is shown in Fig. 6. The first customer was appropriately the University of Illinois PLATO project. This product was a 512 × 512 pixel-array full-graphic display having a square aspect ratio and a diagonal of 12 in.[5] It used the much more robust panel structure Owens-Illinois had pioneered in 1968. The glass plates were now a rugged 6 mm thick and the all-inert-gas mixture was hermetically sealed in with solder glass instead of epoxy. I still have some of these panels and the gas has not become contaminated even after 40 years.

The period from the initial invention of the plasma panel in 1964 until the first product delivery in 1971 was remarkably short. (This concept is reinforced by a quick comparison of Figs. 5 and 6.) By 1975, Owens-Illinois had delivered 1000 of these panels to the University for its PLATO 4 system, which could simultaneously control all 1000 graphics terminals with one computer mainframe.[6]

Further Developments

Over the next 15 years, other companies such as IBM, Fujitsu, NEC, Control Data, Electro Plasma, Photonics, Plasmaco, and AT&T developed more advanced monochrome products that worked on the same principles.[7] The PDP color age started when Fujitsu introduced its 21-in.-diagonal full-color plasma-panel product in 1992 and its 42-in.-diagonal color

***Fig. 6:** Owens-Illinois delivered the first plasma-display-panel product to the University of Illinois in 1971. It was a 12-in.-diagonal 512 × 512-pixel full-graphic display with inherent memory. Photo courtesy Owens-Illinois.*

TV in 1996. Because of strong competition from the LCDs, plasma manufacturers developed the winning strategy of making large-diagonal (42-in. and larger) TV displays. This was not initially possible with AMLCD products. The great success of these plasma products demonstrated that the biggest market for flat-panel displays was for large-screen TVs. The success of the plasma panels in this giant market soon attracted the LCD manufacturers, who followed with their own large-screen TVs. So, not only are the technologies found in the first plasma-display product used in every plasma TV sold today, but this first product also had a major impact on today's LCD TVs.

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OLED Historical Development

OLEDs have long shown promise as a display technology for the future, but many research breakthroughs were necessary in order to make them commercially viable.

by Amal Ghosh and Munisamy Anandan

OLED technology and its promise as a display medium have been a target of research and development for almost as long as the entire 50 year history of SID. In 1963, Martin Pope and his group at New York University made the first observation of DC electroluminescence in anthracene, with an operating voltage of 400 Vdc. In 1965, W. Helfrich and W.G. Schneider produced electroluminescence through double injection of electrons and holes from two different electrodes in anthracene crystal. Intense research of organic electroluminescence was then performed from that time on, but none of the results from this research attracted the display industry until 1987, when a seminal discovery was made by C. W. Tang and S. A. Van Slyke.

Tang and Van Slyke produced organic light-emitting diodes (OLEDs) that used a novel two-layered structure with separate hole-transporting and electron-transporting

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layers such that recombination and light emission occurred in the middle of the organic layer. This resulted in a reduction in operating voltage and improvements in efficiency and led to the current era of OLED research and development. This was reported in their historic paper rather simply titled "Organic Electroluminescent diodes,"[1] which received worldwide attention. In fact, it would not be surprising if this paper has received over 10,000 citations since that time. The low operating voltage and efficiency of light generation that characterized their experiments was very attractive to the display industry, especially when viewed as a potential challenge to the king of displays, the LCD. Eastman Kodak Company started putting this invention to work by licensing the technology and also partnering with other companies for manufacturing.

Small Molecule/Fluorescent OLEDs

The technology developed at Kodak came to be known as "Small-Molecule OLED" (SM-OLED) because the light generation was mainly through singlet excitons. This technology was also known as fluorescent OLED technology and involved not only the OLED based on small molecules, but also (and importantly) a structure for keeping the light-generation zone away from the electrodes. This is the structure of all OLED displays today, whether they be fluorescent, phosphorescent, or polymer OLED. Soon after Tang's invention, monochrome-based OLED passive-matrix (PMOLED) display products started appearing on the market. Pioneer was the first company to introduce monochrome PMOLEDs for car radio systems in 1996. Many mobile phones had PMOLED displays as their main display as well their sub-display.

However, as occurred along a similar evolutionary path for the early days of LCDs, it was soon realized that passive-matrix designs had limitations that prevented them from being suitable for most other high-performance applications. Hence, many companies, including the Sanyo–Kodak joint venture, started working on active-matrix OLED (AMOLED) displays. Early AMOLED display developments included microdisplays developed in 1998–1999 by eMagin Corp., a licensee of Kodak. These displays employed a backplane made of single-crystal silicon. Full-color versions by eMagin employed white OLED pixels with RGB color filters (Fig. 7).

At this time, there was a widely held belief that an a-Si backplane would also work for direct AMOLED displays. Unfortunately, this was shown to be incorrect because of the much lower mobility and relative non-uniformity of TFTs made from amorphous-silicon. While LCD subpixels switch mainly through the application of an electric-field potential, OLED-display subpixels illuminate through the injection of electrical current. The eMagin devices proved that the active-matrix concept was viable, but the substantial differences between single-crystal silicon that eMagin used and amorphous-silicon that others were experimenting with produced less satisfactory results. The Sanyo–Kodak joint venture eventually identified this problem and established that the a-Si backplane was not, in fact, suitable for driving AMOLED displays. Sanyo–Kodak then made a full-color AMOLED displays for digital cameras in 1999–2000 that was based on LTPS (low-temperature polysilicon).

During this period, many companies reduced their efforts with regard to OLED display development, preferring to wait until they could see a clear solution to the problem of suitable active-matrix TFTs. Of course, there are now many examples of direct-view AMOLED displays being produced with polysilicon TFTs as well as some with IGZO TFTs, all with promising results, including both Samsung's and LG Display's 55-in. OLED TVs exhibited at Display Week 2012.

In 2007, Sony was the first company to introduce 11-in. OLED TVs to the market, having overcoming several technology barriers for establishing the reliability of OLEDs. But because the manufacturing processes were not cost-effective enough to scale into a profitable business, Sony withdrew the product 1 year later. Samsung then started mass-producing AMOLED displays for smartphones in 2008. By late 2009, LG had introduced 15-in. OLEDs. And then Sony sold 24.5-in.-diagonal AMOLED displays to the broadcasting sector in 2011.

Phosphorescent OLEDs

In organic electroluminescence, excitons are generated through electron-hole recombination. It is estimated that 25% of the excitons belong to the singlet type, based on the spin status, and 75% belong to the triplet type, again based on spin status. In fluorescent OLEDs, only singlet excitons contribute to the light emission and the transition from 75% of triplet excitons is forbidden by selection rule. This results in heat dissipation and loss of luminous efficiency. Ever since the invention

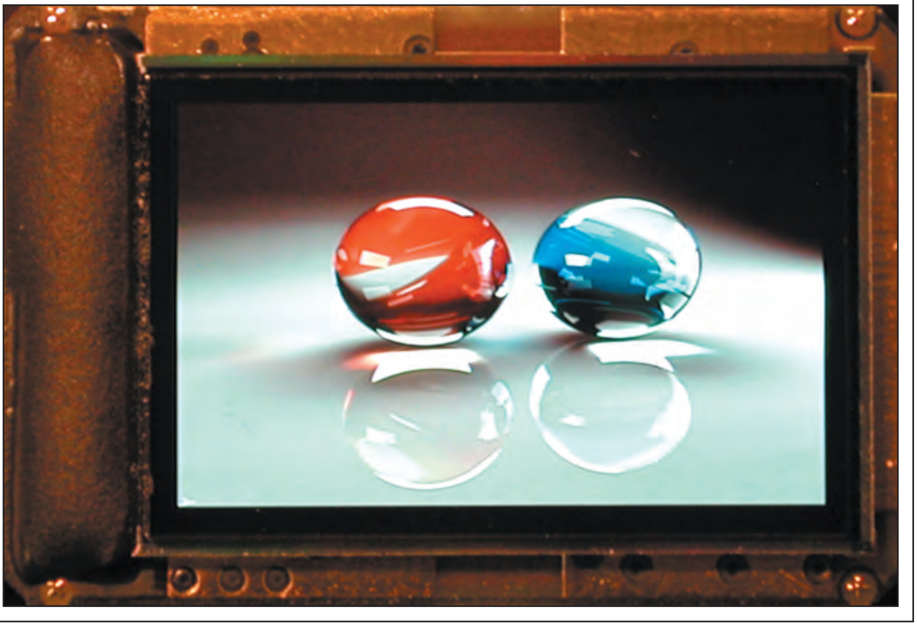

Fig. 7: Full-color microdisplays by eMagin developed in the late 1980s used white OLED pixels with RGB color filters. Photo courtesy eMagin.

of fluorescent OLED technology, research has focused intensely on harvesting triplet excitons because of better luminance efficiency. One such significant step by R. J. Watts *et al*.[2] made possible the occurrence of phosphorescence without fluorescence. But the real breakthrough that attracted the display industry's attention came from the paper on OLED phosphorescence by Marc Baldo *et.al*.[3] This paper opened the door for enabling triplet state excitons to emit light and thus increase the luminous efficiency four-fold.

Since that time, several display companies using this technology licensed from Universal Display Corp. began employing phosphorescent-doped materials in their products. Samsung's AMOLED displays for smartphones employ phosphorescent red dopant. The recently exhibited 55-in. OLED TVs from Samsung and LG at SID's Display Week 2012 employ phosphorescent dopants. LG is employing red and green dopants from the phosphorescent family and blue dopant from the fluorescent family (hybrid OLED) with oxide TFT as the backplane. OLED technology is unique among display technologies in having made the jump in size from a 15-in. OLED TV to a 55-in. OLED TV without going through intermediate sizes such as 27, 32, and 42 in. This type of leap did not occur in LCD technology, as a comparison.

Polymer OLEDs and the Future

Since the invention of small molecules, polymers have been investigated for OLED technology that could result in simplified manufacturing technique and hence low manufacturing cost. The first paper, by Burroughes *et al.*,[4] on conjugated polymer opened the door for polymer LEDs. Display products based on polymer LEDs started appearing in 2002. Philips employed polymer LEDs in an electric shaver in 2002, and Delta Optoelectronics employed polymer LEDs in an MP3 player. Sumitomo Chemical owns rights to polymer-LED technology. Currently, no display product based on polymer LEDs is on the market, but Sumitomo Chemical is planning to mass produce OLED lamps employing polymer-LED technology.

OLED technology has now adequately demonstrated its emergence as the display technology of the future. Its advantages in terms of color, slimness, and absence of backlight are gaining attention in comparison to the current dominant LCD technology.

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Display Week 2012 Review: OLEDs

55 in., 3-D, dual view, flexible IGZO, a-Si, and more.

by Sung Kim and Barry Young

SOCIETY for Information Display (SID) members and others showed up en masse to view the world's most advanced AMOLED displays at the 49th Annual Display Week in Boston. We were surprised to hear at least one well-known financial analyst report that aside from the large AMOLED 3-D TVs, there were no unexpected AMOLED developments at the show. Perhaps the display industry has progressed so far and so quickly that people expect a major technology shift every year. In fact, there was much that was notable at the show, including new backplane technologies, the demonstration of large AMOLEDs with a-Si backplanes, and flexible displays nearing mass production – all far from ho hum developments.

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Ever since CES in January, Samsung and LG have been getting rave reviews for their 55-in. AMOLED TVs, and now we know why. The TVs shown at Display Week were thin, with high contrast, viewability from any angle, and no ghosting. Samsung showed three TVs – a 2-D version, a 3-D version, and a dual-view version (Fig. 1). LG showed only a 3-D version, but it appears that the LG unit is closer to mass production (Fig. 2).

Although the TVs from both companies were 55 in. on the diagonal, had full-HD resolution, and used organic fluorescent and phosphorescent materials, they were constructed very differently, as shown in Table 1. From an image perspective, most people I spoke with thought they were both terrific, with Samsung having a slight edge. Perhaps the difference was the mura on the LG AMOLED, which seemed to be caused by the lack of temporal stability, a characteristic of indium-gallium-zinc-cxide (IGZO) TFTs (see Table 1). Samsung and LG had hoped to be in production in time for the Olympics, but that is not happening. Forecasts by both companies that volume could reach 200,000 units each by the end of 2012 have been toned down to approximately 25,000 each.

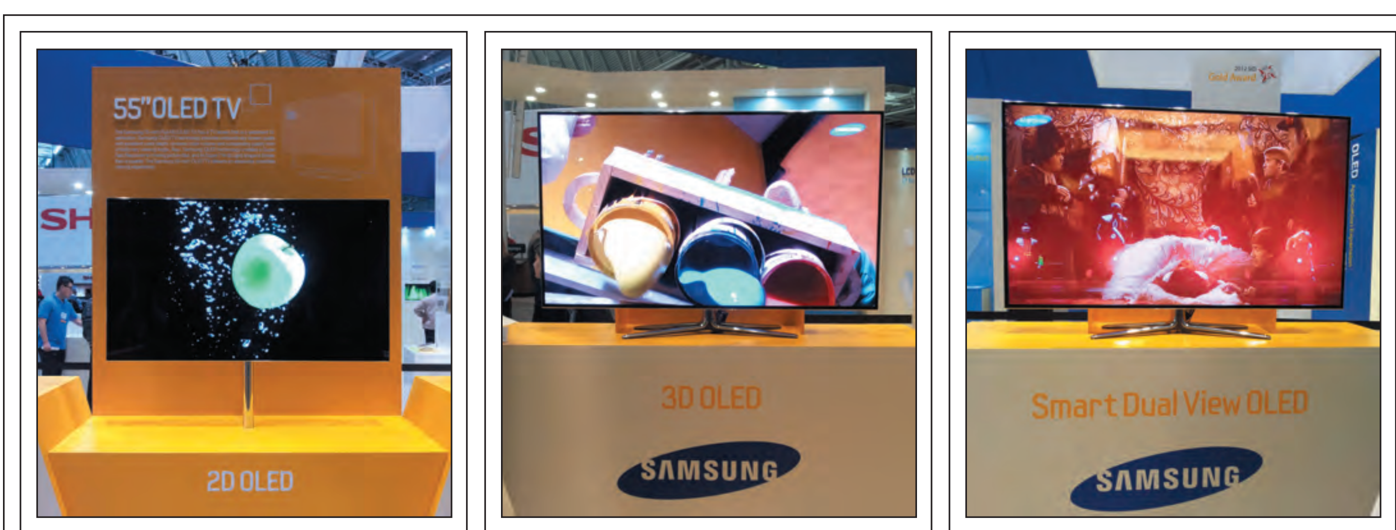

***Fig. 1:** Samsung showed its 55-in. TV in three configurations at Display Week. From left to right are "basic" 2-D imagery, a 3-D version, and a dual-view display that allows two viewers to watch and listen to different content on the same screen. Photo courtesy Samsung/OLED-A.*

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IGNIS Innovation, now operating out of both Canada and Taiwan, showed the world's first 20-in. AMOLED TV with an a-Si backplane (Fig. 3). IGNIS has developed technology that not only compensates for the threshold-voltage shift of the TFT but also the aging of the OLED. For a-Si, IGNIS has designed a more robust process. Some of these developments were discussed in a paper from IGNIS given at the Display Week Symposium, "Stabilized AMOLED Displays by Process Tuning and Backplane OLED Compensation." IGNIS will soon be releasing its first AMOLED product, a 3.5-in. HVGA display on a cell purchased from E Ink, propagated by a color OLED from RiTdisplay.

Table 1: Comparative specifications for LG and Samsung OLED TVs are shown above. Courtesy OLED-A, Companies.

	LG Display	Samsung Display Co.
Manufacturing	Gen 8 6-up	Gen 5.5 2-up
Backplane	IGZO	poly-Si
OLED Architecture	Bottom emission	Bottom emission
Stack	Tandem	Single
Color	Yellow/ orange, blue	Red, green, blue
Patterning	None	LITI
Color Filter	Yes	No
Cover	Glass/metal	Metal
Comparison Material Cost	4-light emitting	3-light emitting
OLED Yield	Medium	High
Transport Yield	Medium	Medium
Backplane Yield	Low	High
Material Utilization	Low	Low
Lifetime	Higher	Lower
Gray Scale	White plus	3 colors
Driving Voltage	2X	X
Cathode	LiF, Al+	LiF, Al+
Power Consumption	Higher	Lower
Differences	Effect of color filter	Gray scales
Cost Comparison	Color filter on array	LTPS
Organics	4 LELs	3 LELs
Generation	_ Gen 8	_ Gen 5.5

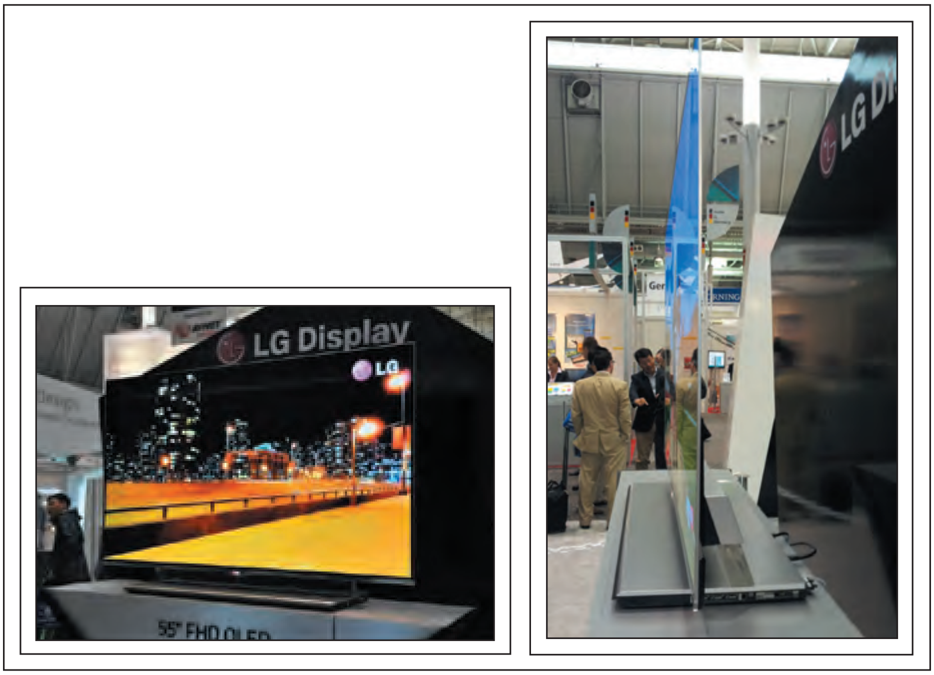

Fig. 2: LG's OLED TV displayed vibrant imagery (left) in an ultra-thin (0.157-in.) package (right). Photo courtesy LG/OLED-A.

Another innovative AMOLED was a 7.4-in. VGA flexible (conformable) display from the Flexible Display Center at Arizona State (Fig. 4). While the display is still in development, the University was able to demonstrate the results of an intensive program that uses a unique bond/debond process, IGZO, and a reusable carrier to produce the backplane. The cover process involved thin film and the OLED deposition and patterning of side-by-side RGB using VTE and FMM. The module process was fairly rudimentary, so there were lots of unattached rows and columns. Nonetheless, this technology demonstrator was a major achievement and a significant step in showing the practicality of flexible AMOLEDs. This OLED panel was developed with funding from the U.S. Army, features 480 × 360 (81 ppi) resolution, has an oxide-TFT (IGZO) backplane, and is built on a PEN (polyethylene naphthalate) substrate. It was developed in collaboration with Universal Display Corp., DuPont (Teijin Films), Sunic, and Henkel.

Chimei Innolux (CMI) showed up at Display Week for the first time with its pre-release small-to-medium displays that included 3.4- and 4.3-in. AMOLED panels (one shown in Fig. 5). A few days before Display Week, CMI announced that it will begin to produce these panels by Q4 2012. At the show we learned that the first OLED fab to go online is actually an old TPO/

Fig. 3: IGNIS has introduced a 20-in. AMOLED with an a-Si backplane. Photo courtesy IGNIS/OLED-A.

Fig. 4: *Arizona State's 7.4-in. flexible OLED was one of the more impressive prototypes shown at the exhibit. Photo courtesy Arizona State University/OLED-A.*

Fig. 5: *Chimei Innolux's 3.4-in panel is one of two AMOLED displays the company says will enter production in Q4 2012. Photo courtesy Chimei Innolux/OLED-A.*

Toppoly Gen 3.5 fab. The panels will use LTPS backplanes and will both feature 960 × 540 resolution (translating to 324 ppi on the 3.4-in. panel and 256 ppi on the 4.3-in. panel). CMI says that its technology is "ready" for 4.5-in. 720p (326 ppi) panels as well. CMI uses white OLEDs with a color filter, so processes are not limited by the use of a fine metal mask.

Samsung Mobile Display (now Samsung Display Co.; see Industry News article in this issue) also showed a range of small-to-medium AMOLED displays for the Galaxy S2 and 3, Galaxy Note, and the first AMOLED tablet. The sizes were 4.3, 4.65, 4.8, 5.3, and 7.7 in., respectively. Samsung has now fully adopted the PenTile technology for its high-pixel-density (>250 ppi) panels. For OLEDs, the PenTile approach maintains brightness, which results in an increase in lifetime. At >250 ppi, it is indistinguishable from side-by-side designs for all but the advanced image experts such as DisplayMate. Joel Pollack, Senior Vice President for PenTile developer Nouvoyance Inc., says, "PenTile technology is now used in 100% of production products with OLED displays of greater than 230 ppi. Products using PenTile OLEDs have won an SID DYA Gold Award 2 consecutive years (Samsung Galaxy S and Galaxy Note). With the unprecedented adoption by consumers of the new Galaxy S3 with a 4.8-in. PenTile OLED, it seems that the market has voted with their wallets for phones with PenTile OLED displays."

Speaking of no-shows, Sharp made a major announcement the week before Display Week that indicated the company was reversing its no-OLED policy, and revealed a 13.4-in. and a flexible OLED using IGZO. One of the OLED news sites picked up the announcement and reported that the displays would be shown at Display Week. But most of the people in the Sharp booth had no clue that Sharp had even reversed its policy and there were no OLED displays. Too bad, as Sharp had a major opportunity to make news by demonstrating why it has reversed course so dramatically. Could it be that the Hon Hai, Sharp, and Apple relationship was just too new to announce that Apple now has a supplier, not named Samsung, which is capable of providing flexible AMOLEDs?

Both eMagin Corp. and Fraunhofer IPMS showed up with OLED microdisplays, which keep improving from both a resolution and a power-consumption perspective. With the backlight eliminated, OLED microdisplays are the most efficient near-to-eye products currently available and are getting a lot of play in the area of futuristic integrated displays and glasses. The eMagin display had WUXGA (1920 × 1200) resolution with additional rows and columns that brought the total pixel count up to 1944 × 1224. The extra rows and columns allow the image to be shifted in 1-pixel increments for optical centering of the image. The full-color imager uses eMagin XL technology: a white OLED with a color-filter array. Subpixels were 3.2 μm x 9.6 μm to produce a 9.6-μm-square full-color pixel with a fill factor of 71%. The Fraunhofer IPMS HMD was only VGA, but the unit used the Fraunhofer bidirectional OLED backplane. The bidirectional OLED has a backplane that acts as both a microdisplay and a camera sensor to allow eye tracking in HMDs. The microdisplay has one camera pixel for every OLED pixel. (This technology won a Best-in-Show award this year; see the Best-in-Show article in this issue.)

A number of Chinese display manufacturers have announced the goal of building AMOLEDs

Fig. 6: Tianma showed a 12.1-in. WVGA prototype. Photo courtesy Tianma/OLED-A.

using LTPS and VTE, but only Tianma actually showed up at Display Week with a demo, a 12.1-in. WVGA panel that looked good (Fig. 6). Tianma doesn't expect to commercialize the demo, as it intends to concentrate on smartphone applications 5-in. and below. Tianma will install a Gen 5.5 LTPS fab for LCDs this year and hopes to convert it to AMOLEDs by the end of 2013.

Clearly, important developments in OLED technology were shown at Display Week. As mentioned earlier, perhaps the media and financial analysts have been so spoiled or are a little jaded by the pace of change that they are no longer easily impressed. What has to happen to excite these individuals; something like turning wallpaper into displays at no cost? ■

special advertising feature

OLED Technology Prepares for Landing in the Commercial TV Market

LG Display reflects on events leading up to the exhibit of its 55-in. OLED display and explains what to expect going forward.

by LG Display

WHEN introduced earlier this year, large-sized organic light-emitting-diode (OLED) technology made TV display technology exciting again – reigniting interest in an industry outshone by advances in smartphones and tablets over the last few years. At CES 2012, stunning images, displayed in a quality never before seen via a TV set, left the record 153,000 visitors to the tradeshow abuzz over 55-in. OLED TVs from set makers such as LG and others. The new TVs were also exhibited recently at Display Week 2012, exciting an even more-demanding audience of display-technology experts (Fig. 1).

Fast-forward several months, and anticipation is again mounting as manufacturers prepare for the upcoming commercial release of the first 55-in. OLED-TV units by significantly investing in new OLED-panel production lines.

LG received wide acclaim for its 55-in. OLED panel – utilized by sister company LG Electronics in its new 55-in. TV model – which won both the prestigious "Best-of-CES 2012" award and "Best-in-Show" award at Display Week 2012. Here, in a special update to *Information Display* magazine, OLED developer and manufacturer LG Display describes the impetus for developing large OLED panels and what to expect for the technology going forward.

LG Display Co., Ltd., *is a leading manufacturer and supplier of thin-film-transistor liquid-crystal-display (TFT-LCD) panels, OLEDs, and flexible displays. The company provides TFT-LCD panels in a wide range of sizes and specifications for use in TVs, monitors, notebook PCs, tablets, mobile products, and various other applications. For more information regarding LG Display and its 55-in. OLED-TV panel, please visit the company's website at http://www.lgdisplay.com.*

How We Got Here

"We found ourselves wrestling with two issues: the need to push beyond LCD-TV technology and whether OLED was the right mechanism to accomplish that."

– Dr. James Lee, Technology Fellow
OLED Development Department, LG Display

Fig. 1: *LG Display's 55-in. TV panel was shown at CES and Display Week 2012.*

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A few years ago, murmurs began to circulate about stagnation in the flat-panel TV market. LCD and plasma TVs had propelled the industry forward in 2006 as consumers eagerly replaced their bulky cathode-ray-tube (CRT) TVs in favor of the sleeker, high-definition sets. By 2011, however, demand appeared to have slowed, with research firm DisplaySearch forecasting a 1% annual decline in flat-panel TV sales across developed countries such as the U.S. and Europe.

Although partly attributable to the global economic slump, other factors such as rapid advancements in smartphone and tablet technology played a part in the weakening demand. While LCD-TV technology was not anywhere near on its way out (LCD units still account for 90% of current global TV sales), it was clear that the industry needed an infusion of fresh energy.

Researchers at LG Display, including Dr. James Lee, who has been experimenting with OLED for the better part of his career, quickly began to consider the technology as a potential game changer due to its strengths in the quality of the display and the advantages of certain design elements of the TV set itself; the two most critical factors for a successful consumer TV set. As Dr. Lee explained, "We realized that the application of OLED to large-sized TV panels was a canvas full of enormous potential, yet no one, at that point, had made it work."

At the time, in fact, OLED displays were only being utilized in a limited number of smartphone models – and with noticeable problems at that, such as high power consumption and poor outdoor visibility. LG Display researchers soon realized that the issues that made OLED so troublesome for mobile devices were not applicable to larger TV sets. TV is viewed in a very different environment from mobile devices. Utilized indoors, the key requirements of an effective TV set are vivid picture quality as well as a slim and light design for easy installation; both factors that OLED technology is particularly well suited for. By contrast, smartphones and tablets are mainly used to read text and view still images both indoors and outdoors. Therefore, features such as high pixel density, as well as efficient battery consumption, take precedence.

Armed with this philosophy, LG Display changed course to pursue the application of OLED to TVs, and a different technology known as AH-IPS (Advanced High Performance In-Plane Switching) to smartphones and tablets. The company's innovative efforts to develop large-sized OLED-TV panels quickly resulted in breakthroughs beyond existing LCD technology.

Beyond LCD

To understand just what LG Display achieved, it is important to understand the basics of OLED technology. Just like a discrete LED, an OLED cell is a self-emitting device that produces light based on the amount of electrical energy applied to it. It does not require a separate backlight in order to produce light, in contrast with LCDs. When OLED cells are fabricated in three primary colors and arranged on a substrate in a rectangular pattern very similar to how LCD color sub-

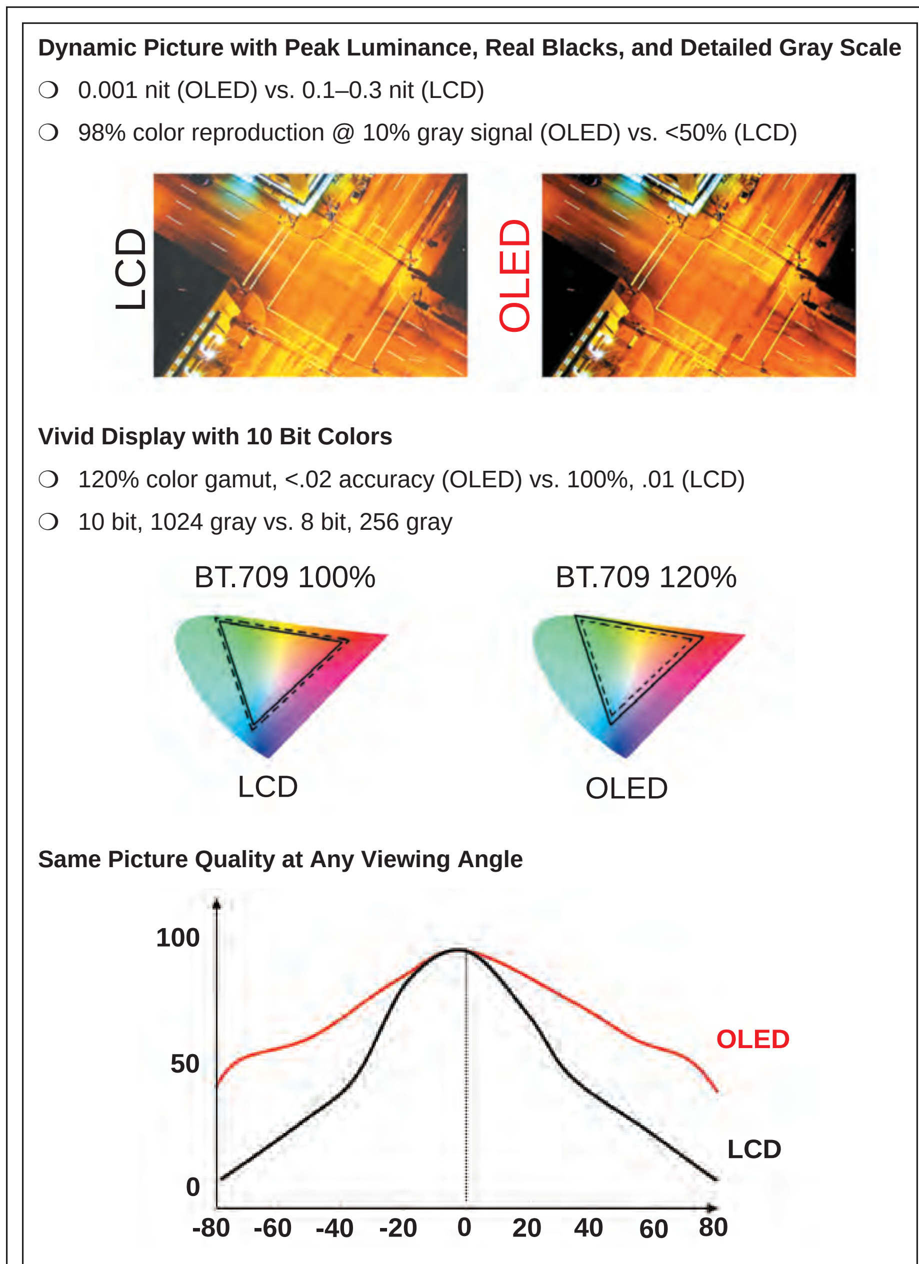

Fig. 2: Picture-quality benefits of OLEDs over LCDs.

pixels are arranged; a full-color high-resolution display can be fabricated. OLED technology features a response time to electric signals over 1000 times faster than liquid.

OLED panels are therefore able to produce remarkable image quality with no motion blur due to their fast response time, as well as dark-room contrast ratios of over 100,000:1. OLED panels also produce richer colors than LCD panels, with OLED achieving 120% of the BT.709 TV color standard, while most LCD TVs achieve roughly 100%. Also worth noting, OLED panels produce consistent picture quality at any viewing angle, an important feature for a family TV (Fig. 2).

LG Display's accomplishments have also involved improvements in physical TV set design potential. For instance, OLED's ability to operate without a backlight means a display 80% thinner and lighter than an LCD. Also, with no need for a backlight or liquid crystal, there is potential for developing curved OLED panels without any degradation of picture performance (Fig. 3).

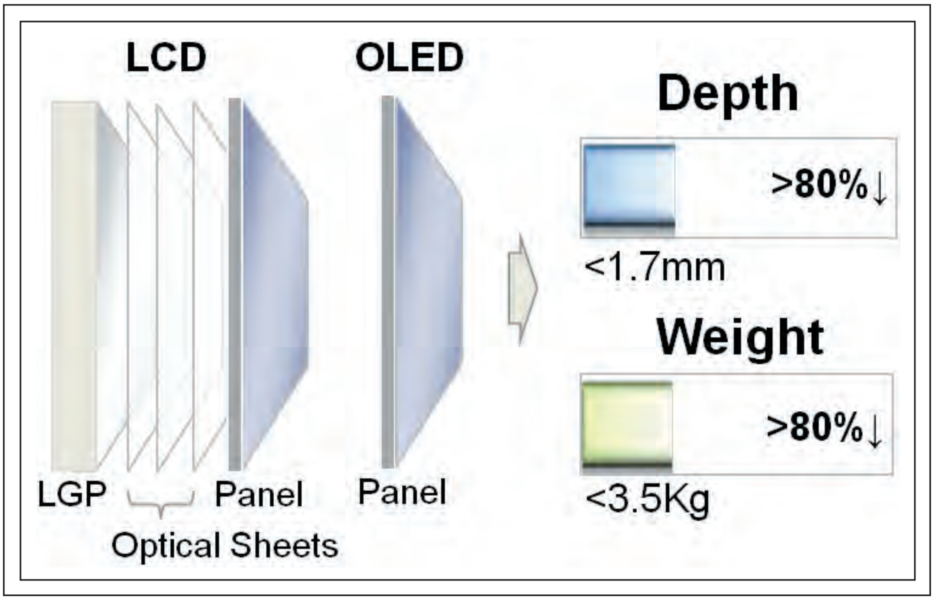

Fig. 3: OLED's one-panel design makes it easier for developers to create thinner, lighter TVs.

WRGB OLED

With LG Display beginning mass production of 55-in. OLED TV panels in the second half of 2012, the appearance of retail OLED-TV sets is just around the corner. Given the timing, the differences between the two versions of large-sized OLED that will be sold, RGB (red, green, blue) and WRGB (white, red, green, blue), are worth examining, as the choice will matter significantly to both consumers and manufacturers. LG Display's 55-in. OLED-TV display, which adopts a WRGB OLED top panel and oxide-TFT-type base panel, provides terrific insight into the advantages of WRGB.

LG Display's 55-in. OLED-TV panel utilizes an oxide-TFT-based panel and a pixel structure called a WRGB (white, red, green, blue) OLED for its top panel. Screen information is displayed through a color refiner below the TFT-based panel that, without risking color interference, leads to a low error rate, higher productivity, and clearer ultra-definition (UD) screen via the benefit of small pixels.

Furthermore, WRGB OLED realizes identical colors from wide viewing angles through color information displayed through a thin layer. The higher energy efficiency of WRGB OLEDs, especially when considering web-browsing applications for smart TVs, is a key strength. Specifically, the use of white pixels allows WRGB OLED panels to consume less electricity than RGB OLED panels.

WRGB OLED also provides a better return on investment for manufacturers, especially critical as the technology is first introduced to

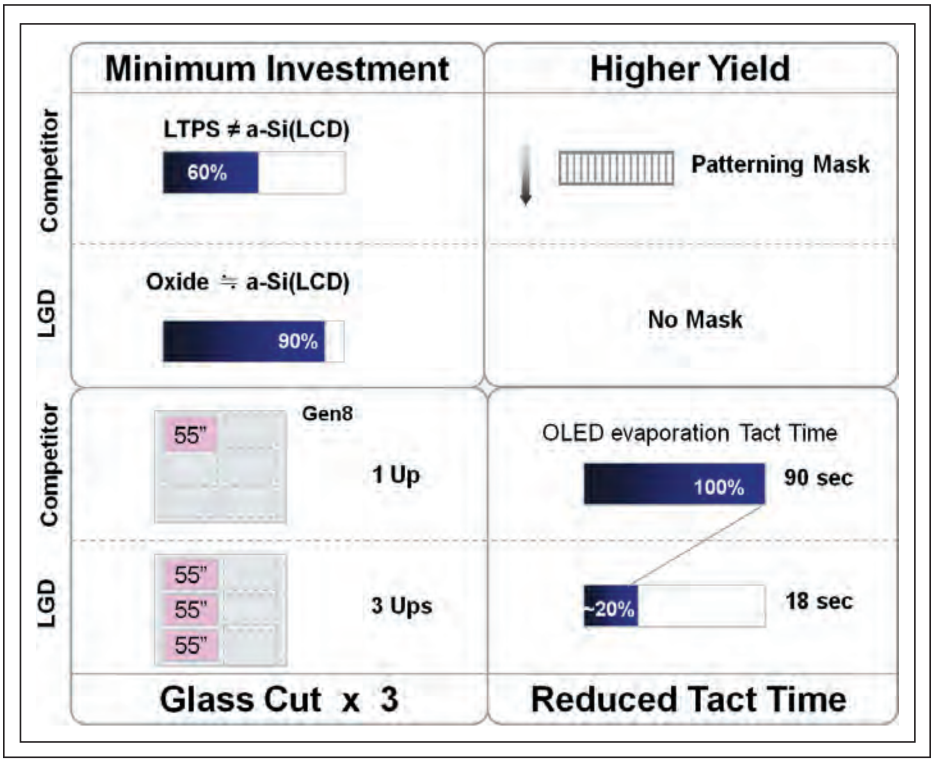

Fig. 4: This chart compares the productivity benefits of LG OLED technology over other types of OLED implementations.

the market. Compared to RGB OLEDs, WRGB OLEDs require 50% less investment in facilities and equipment with a higher yield rate. Clearly, WRGB OLEDs are ideal for large-screen TVs due to their quality and cost benefits.

In addition, LG Display's use of an oxide-TFT-based panel instead of the low-temperature-polysilicon (LTPS) panel used in existing small-sized OLED panels results in faster and more sophisticated processing of light quantity and color information. The oxide-TFT process that LG Display utilizes is similar to the existing a-Si TFT process, with the difference lying in replacing amorphous-silicon with indium gallium zinc oxide (IGZO), which produces image quality that is identical to high-performance LTPS-based panels at significantly reduced investment levels.

What to Anticipate Further Down the Road

In addition to vibrant imagery in a razor-thin design, LG Display's 55-in. OLED TV panel will from the outset incorporate additional innovative features such as film-patterned retarder (FPR) 3-D technology. And the commercial introduction of OLED TV sets is only just the beginning. For example, as the first OLED-TV units will be marketed as premium products, manufacturers have opted to begin with a 55-in. size, currently the largest screen size in the high-tier TV market.

As technology progresses, sizes are expected to vary and prices to come down. LG Display expects that OLED TV will reach a price premium of 50% in about 2015; this is when the market will start to grow. In addition, features such as OLED power consumption are constantly being improved, and the introduction of curved OLED-TV units is also not far off. The next generation of TV technology is now upon us, and consumers as well as the industry are justified for their excitement at what lies ahead. ■

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SID 2013 honors and awards nominations

On behalf of the SID Honors and Awards Committee (H&AC), I am appealing for your active participation in the nomination of deserving individuals for the various SID honors and awards. The SID Board of Directors, based on recommendations made by the H&AC, grants all the awards. These awards include five major prizes awarded to individuals, not necessarily members of SID, based upon their outstanding achievements. The **Karl Ferdinand Braun prize** is awarded for ***"Outstanding Technical Achievement in, or contribution to, Display Technology."*** The prize is named in honor of the German physicist and Nobel Laureate Karl Ferdinand Braun who, in 1897, invented the cathode-ray tube (CRT). Scientific and technical achievements that cover either a wide range of display technologies or the fundamental principles of a specific technology are the prime reasons for awarding this prize to a nominee. The **Jan Rajchman prize** is awarded for ***"Outstanding Scientific and Technical Achievement or Research in the Field of Flat-Panel Displays."*** This prize is specifically dedicated to those individuals who have made major contributions to one of the flat-panel-display technologies or, through their research activities, have advanced the state of understanding of one of those technologies. The **Otto Schade prize** is awarded for ***"Outstanding Scientific or Technical Achievement in the Advancement of Functional Performance and/or Image Quality of Information Displays."*** This prize is named in honor of the pioneering RCA engineer Otto Schade, who invented the concept of the Modulation Transfer Function (MTF) and who used it to characterize the entire display system, including the human observer. The advancement for this prize may be achieved in any display technology or display system or may be of a more general or theoretical nature. The scope of eligible advancement is broadly envisioned to encompass the areas of display systems, display electronics, applied vision and display human factors, image processing, and display metrology. The nature of eligible advancements may be in the form of theoretical or mathematical models, algorithms, software, hardware, or innovative methods of display-performance measurement, and image-quality characterization. Each of these above-mentioned prizes carries a $2000

SID honors and awards nominations

Nominations are now being solicited from SID members for candidates who qualify for SID Honors and Awards.

- KARL FERDINAND BRAUN PRIZE. Awarded for an outstanding *technical* achievement in, or contribution to, display technology.
- JAN RAJCHMAN PRIZE. Awarded for an outstanding *scientific* or *technical* achievement in, or contribution to, research on flat-panel displays.
- OTTO SCHADE PRIZE. Awarded for an outstanding *scientific* or *technical* achievement in, or contribution to, the advancement of functional performance and/or image quality of information displays.
- SLOTTOW–OWAKI PRIZE. Awarded for outstanding contributions to the education and training of students and professionals in the field of information display.
- LEWIS & BEATRICE WINNER AWARD. Awarded for exceptional and sustained service to SID.
- FELLOW. The membership grade of Fellow is one of unusual professional distinction and is conferred annually upon a SID member of outstanding qualifications and experience as a scientist or engineer in the field of information display who has made widely recognized and significant contribution to the advancement of the display field.
- SPECIAL RECOGNITION AWARDS. Presented to members of the technical, scientific, and business community (not necessarily SID members) for distinguished and valued contributions to the information-display field. These awards may be made for contributions in one or more of the following categories: (a) outstanding technical accomplishments; (b) outstanding contributions to the literature; (c) outstanding service to the Society; (d) outstanding entrepreneurial accomplishments; and (e) outstanding achievements in education.

Nominations for SID Honors and Awards must include the following information, preferably in the order given below. Nomination Templates and Samples are provided at *www.sid.org/awards/nomination.html*.

1. Name, Present Occupation, Business and Home Address, Phone and Fax Numbers, and SID Grade (Member or Fellow) of Nominee.

2. Award being recommended:
   Jan Rajchman Prize
   Karl Ferdinand Braun Prize
   Otto Schade Prize
   Slottow–Owaki Prize
   Lewis & Beatrice Winner Award
   Fellow*
   Special Recognition Award

*Nominations for election to the Grade of Fellow must be supported in writing by at least five SID members.

3. Proposed Citation. This should not exceed 30 words.

4. Name, Address, Telephone Number, and SID Membership Grade of Nominator.

5. Education and Professional History of Candidate. Include college and/or university degrees, positions and responsibilities of each professional employment.

6. Professional Awards and Other Professional Society Affiliations and Grades of Membership.

7. Specific statement by the nominator concerning the most significant achievement or achievements or outstanding technical leadership that qualifies the candidate for the award. This is the most important consideration for the Honors and Awards committee, and it should be specific (citing references when necessary) and concise.

8. Supportive material. Cite evidence of technical achievements and creativity, such as patents and publications, or other evidence of success and peer recognition. Cite material that specifically supports the citation and statement in (7) above. (Note: the nominee may be asked by the nominator to supply information for his candidacy where this may be useful to establish or complete the list of qualifications).

9. Endorsements. Fellow nominations must be supported by the endorsements indicated in (2) above. Supportive letters of endorser will strengthen the nominations for any award.

E-mail the complete nomination – including all the above material by **October 8, 2012** – to fan.luo@auo.com or sidawards@sid.org or by regular mail to:
Fan Luo, Honors and Awards Chair, Society for Information Display,
1475 S. Bascom Ave., Ste. 114, Campbell, CA 95008, U.S.A.

stipend sponsored by AU Optronics Corp., Sharp Corporation, and Samsung Mobile Display, respectively.

The **Slottow–Owaki prize** is awarded for ***"Outstanding Contributions to the Education and Training of Students and Professionals in the Field of Information Display."*** This prize is named in honor of Professor H. Gene Slottow, University of Illinois, an inventor of the plasma display and Professor Kenichi Owaki from the Hiroshima Institute of Technology and an early leader of the pioneering Fujitsu Plasma Display program. The oustanding education and training contributions recognized by this prize is not limited to those of a professor in a formal university, but may also include training given by researchers, engineers, and managers in industry who have done an outstanding job developing information-display professionals. The Slottow–Owaki prize carries a $2000 stipend made possible by a generous gift from Fujitsu, Ltd., and Professor Tsutae Shinoda.

The fifth major SID award, the **Lewis and Beatrice Winner Award,** is awarded for ***"Exceptional and Sustained Service to the Society."*** This award is granted exclusively to those who have worked hard over many years to further the goals of the Society.

The membership grade of **SID Fellow Award** is one of unusual professional distinction. Each year the SID Board of Directors elects a limited number (up to 0.1% of the membership in that year) of **SID members** in good standing to the grade of **Fellow.** To be eligible, candidates must have been members at the time of nomination for at least 5 years, with the last 3 years consecutive. A candidate for election to Fellow is a member with ***"Outstanding Qualifications and Experience as a Scientist or Engineer in the Field of Information Display who has made Widely Recognized and Significant Contributions to the Advancement of the Display Field"*** over a sustained period of time. SID members practicing in the field recognize the nominee's work as providing significant technical contributors to knowledge in their area(s) of expertise. For this reason, five endorsements from SID members are required to accompany each Fellow nomination. Each Fellow nomination is evaluated by the H&AC, based on a weighted set of five criteria. These criteria and their assigned weights are creativity and patents, 30%; technical accomplishments and publications, 30%; technical leadership, 20%; service to SID, 15%; and other accomplishments, 5%. When submitting a Fellow award nomination, please keep these criteria with their weights in mind.

The **Special Recognition Award** is given annually to a number of individuals (membership in the SID is not required) of the scientific and business community for distinguished and valued contribution in the information-display field. These awards are given for contributions in one or more of the following categories: (a) ***Outstanding Technical Accomplishments,*** (b) ***Outstanding Contributions to the Literature,*** (c) ***Outstanding Service to the Society,*** (d) ***Outstanding Entrepreneurial Accomplishments,*** and (e) ***Outstanding Achievements in Education.*** When evaluating the Special Recognition Award nominations, the H&AC uses a five-level rating scale in each of the above-listed five categories, and these categories have equal weight. Nominators should indicate the category in which a Special Recognition Award nomination is to be considered by the H&AC. More than one category may be indicated. The nomination should, of course, stress accomplishments in the category or categories selected by the nominator.

While an individual nominated for an award or election to Fellow may not submit his/her own nomination, nominators may, if necessary, ask a nominee for information that will be useful in preparing the nomination. The nomination process is relatively simple, but requires that the nominator and perhaps some colleagues devote a little time to preparation of the supporting material that the H&AC needs in order to evaluate each nomination for its merit. It is not necessary to submit a complete publication record with a nomination. Just list the titles of the most significant half a dozen or less papers and patents authored by the nominee, and list the total number of papers and patents he/she has authored.

Determination of the winners for SID honors and awards is a highly selective process. Last year less than 30% of the nominations were selected to receive awards. Some of the major prizes are not awarded every year due to the lack of sufficiently qualified nominees or, in some cases, because no nominations were submitted. On the other hand, once a nomination is submitted, it will stay active for three consecutive years and will be considered three times by the H&AC. The nominator of such a nomination may improve the chances of the nomination by submitting additional material for the second or third year that it is considered, but such changes are not required.

Descriptions of each award and the lists of previous award winners can be found at *www.sid.org/awards/indawards.html*. Nomination forms are available at *www.sid.org/awards/nomination.html* where you will find Nomination Templates in both MS Word (preferred) and Text formats. Please use the links to find the Sample Nominations, which are useful for composing your nomination since these are the actual successful nominations for some previous SID awards. Nominations should preferably be submitted by e-mail. However, you can also submit nominations by ordinary mail if necessary.

Please note that with each Fellow nomination, only five written endorsements by five SID members are required. These brief endorsements – *a minimum of 2–3 sentences* to a maximum of one-half page in length – *must state why clearly and succinctly, in the opinion of the endorser, the nominee deserves to be elected to a Fellow of the Society. Identical endorsements by two or more endorsers will be automatically rejected* (no form letters, please). Please send these endorsements to me either by e-mail (preferred) or by hardcopy to the address stated in the accompanying text box. Only the Fellow nominations are required to have these endorsements. However, I encourage you to submit at least a few endorsements for all nominations since they will frequently add further support to your nomination.

All 2013 award nominations are to be submitted by October 8, 2012. E-mail your nominations directly to fan.luo@auo.com or sidawards@sid.org. If that is not possible, then please send your hardcopy nomination by regular mail.

As I state each year: "In our professional lives, there are few greater rewards than recognition by our peers. For an individual in the field of displays, an award or prize from the SID, which represents his or her peers worldwide, is a most significant, happy, and satisfying experience. In addition, the overall reputation of the society depends on the individuals who are in its 'Hall of Fame.'

When you nominate someone for an award or prize, you are bringing happiness to an individual and his or her family and friends, and you are also benefiting the society as a whole."

Thank you for your nomination in advance.

— Fan Luo
Chair, SID Honors & Awards Committee

Tom Curran 1926–2012

Thomas Vincent Curran, a strong supporter and long-time active member of the Society for Information Display, passed away on June 12, 2012, in Beaverton, Oregon. Tom is survived by his wife Nancy Johnson and his children Mary Jeanne Reynales, Jane Pandell, Joanne Angel, Juliana Terian, Thomas Curran, Jennifer Steets, and Frances Rossi. He also leaves behind his adored stepdaughters, grandchildren, and great-grandchildren.

Tom was a charter member of the Society, one of 64 individuals so designated in a list dating from 1966. He served as publications chair for SID from 1975 to 1982 and from 1988 to 1992, receiving a presidential citation for his work. He was very active in both the Los Angeles and the Pacific Northwest chapters of the Society, helping the Pacific Northwest (PNW) chapter to commence activity. He also served as nominations and awards committee chair for the PNW-SID chapter in 2001. Tom was granted a Life Membership for his longtime commitment to SID.

Tom was born in Los Angeles in 1926. He spent most of his youth and adult life in the Los Angeles area, where he raised his family and worked in marketing and sales in the electronics and information-display industries. He attended Pierce Community College and UCLA and received a certificate in advanced management from Ohio State University. He also spent several years with companies in Los Gatos, CA, and Horsham, PA. In 1988, he moved to Oregon and started working at Planar Systems as a marketing representative for EL panels and later in Planar Advanced for military AMLCDs.

Tom retired in 2001. However, he continued to participate actively in the local Pacific Northwest chapter. He was a devoted father with a fondness for tinkering (and fixing) electronics of all kinds and was also an enthusiastic and accomplished jazz musician.

Here are just two of many testimonials offered by former colleagues at SID:

"Tom was both a gentleman and a gentle man, neither of which prevented him from persistently pressing home points he felt were important, but not in such a way that you could ever take offense." – Ken Werner, Nutmeg Consultants

"He was polite to all and completely honest in his dealings with people. For that reason he was respected and appreciated by all that knew him in the display industry." – Chris King, Founder, Planar Systems.

SID Elects New Executive Leadership Team

At Display Week 2012 in Boston, the Society for Information Display announced new executive committee members as elected by the members of the Society. The team, which will lead for the next 2 years, is composed of distinguished display-industry veterans from around the world: Brian Berkeley, president; Amal Ghosh, president-elect; Yong-Seog Kim, treasurer; and Helge Seetzen, secretary. In addition, three regional vice-presidents were also introduced: Dave Eccles (Americas), Baoping Wang (Asia), and Jutta Rasp (Europe).

"It's been an incredible honor and irreplaceable experience to spend 2 years at the helm of SID," remarked Munisamy Anandan, SID's outgoing president. "SID is the premier display-technology organization in the world and has attracted the very best display technologists while fostering leading-edge research and development throughout the industry."

New SID president Berkeley noted, "I would first like to thank Dr. Anandan for all his efforts over the last 2 years as head of this organization. Under his steady leadership, SID entered a fresh decade, helping to promote the new cutting-edge display technologies that we're starting to see in our everyday lives." He continued, "I am honored to assume this tremendous responsibility and look forward to ushering in the next generation of incredible, dynamic technologies that shape our ever-evolving space. I look forward to the challenge of ensuring that SID keeps pace and of furthering its reputation as the leading organization for both the present and future of the display industry."

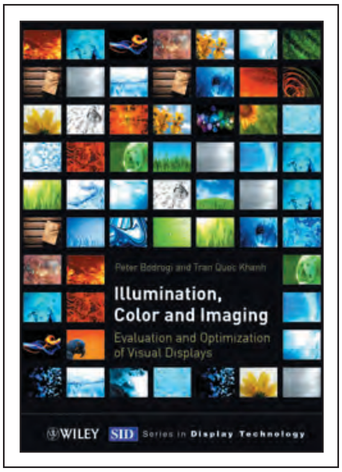
Outside of his role as SID president, Brian Berkeley serves as senior vice-president of OLED Development at Samsung Display Company's San Jose Lab. Berkeley, who has been with Samsung since 2003, is also a 20-year veteran of Apple Computer, where he led all display development activities. In addition to authoring several papers and patents, he is recognized for numerous accomplishments, including his current work in large-area OLED displays. Berkeley is also credited with developing the world's first high-volume liquid-crystal-display (LCD) monitor and first wide-format notebook and monitor displays.

New president-elect Amal Ghosh also serves as senior vice-president at eMagin Corp. With more than 2 decades of industry experience and numerous publications and patents to his credit, he is a recognized expert in the areas of OLED and field-emission displays (FEDs). SID's new treasurer, Professor Yong-Seog Kim, is a distinguished professor at Hongik University in Seoul, Korea. Secretary Helge Seetzen serves as CEO of TandemLaunch Technologies and has spent time in executive roles at both Dolby and BrightSide Technologies. Americas Regional VP Dave Eccles is with Rockwell Collins; Asia Regional VP Baoping Wang is with Southeast University, and Europe Regional VP Jutta Rasp is with FPExperts. ■

book reviews

Illumination, Colour and Imaging: Evaluation and Optimization of Visual Displays

by Peter Bodrogi and Tran Quoc Khanh
Reviewed by Janos Schanda
SID–Wiley Series



Illumination, Colour and Imaging by Peter Bodrogi and Tran Quoc Khanh is an exceptionally interesting, unique piece of work whose title suggests an overview of light, color, and imaging. (The subtitle narrows the subject to visual displays.) Rather than a textbook, it is more a compendium of research results from the authors and their collaborators as performed over the past 2 decades. The descriptions of the achievements of the authors are supplemented by a review of results obtained by other researchers, rounding off the work as a comprehensive overview of two subject areas: visual displays and color rendering.

The authors begin with some fundamental research on color vision as it relates to self-luminous display technologies. Here, one finds pointers to other chapters of the book where topics such as long-term memory effects and questions of visually evoked emotions will be discussed.

Next, the authors deal with colorimetric and color-appearance-based characterization of displays. They report their own experience of monitor calibration, differences compared to sRGB, problems with channel interdependence, and similar questions. This is not a primer from which to learn basic calibration principles, but if the reader has already learned the fundamentals, the descriptions in this chapter will help provide a deeper understanding, as well as ways to avoid some pitfalls. As this section deals mainly with the experience of one of the authors and reviews his work of the past 10–15 years, some of the examples refer to technologies (power-supply overload problems with CRT monitors and visual-angle questions of early LCD monitors) that have been surpassed by new developments. In other areas, the authors offer interesting details, such as where they discuss their experiments for color-appearance studies with total immersion into a colored surrounding.

Chapter 3 deals with ergonomic issues (even if the reviewer might question its title, which proposes the "enhancement of color displays; naturally, the display cannot be enhanced, only the quality of the images produced.) Issues such as visual acuity, its background luminance dependence, the focusing ability of the observer, luminance dependence, time dependence of adaptation, *etc.*, are discussed in the introductory part of the chapter. The authors review the principles of ergonomic color design, together with the use of color to increase legibility and conspicuity. The effect of chromaticity contrast on search performance is introduced, with the example of an experiment performed by one of the authors.

An interesting section of this discussion of ergonomic issues deals with long-term memory colors and their intercultural differences (another area in which one of the authors, together with collaborators, performed fundamental research). Memory colors are those of familiar objects as remembered by the observer; *e.g.*, the color of a ripe banana is familiar to everybody, but if asked to point in a color atlas to the color of a banana, an individual will select a color different from that of the actual banana. This shift between the real banana color and the color reproduced from memory is an interesting and important issue when colors are selected, for example, in virtual environments. The authors provide hints as to how color quality can be increased using memory colors. Color image quality is influenced by white-point selection and local and global contrast, items dealt with further on, where age-related effects are also discussed. A thorough summary that could help orient readers with regard to the many very important questions – not addressed in other books in such a detailed form – would make this chapter even more useful.

The next chapter deals in detail with the special application of color image processing: management and image quality in the film- and TV-studio environment. The very detailed and competent treatment of the subject found here certainly is not equalled in any other books. The chapter provides an insight into the colorimetry of present-day film and TV studios and discusses the entire process, starting with an overview of camera technology and a comparison with conventional chemical film technologies, pointing out items still necessary for development. Questions of intermediate processing and final film production are reviewed and color-quality experiments described (here, also, one of the authors could refer more to his long experience and research results). Readers receive insight into colorimetric problems and the use of different color-appearance models and are guided as to how different pitfalls can be avoided. Perceptual and image-quality aspects of the different processes, among other questions of compression, are discussed, and performance and results of image-quality experiments described. One subsection deals with watermarking and another, which is particularly interesting, discusses visually evoked emotions in color motion pictures.

A description of how to provide the best pixel architecture for displays rounds off the description of display color. Topics such as target color sets, factors of optimization color gamut and large-gamut settings, white-point selection, optimum color primaries, and the possibility of optimizing subpixel architecture (color fringe artifacts) are all discussed and explained by experiments performed by the authors.

The next-to-last chapter jumps to a different subject: color rendering of light sources, which deserves a book all to itself. In this respect, the discussion is slightly out of balance compared to other sections. However, the authors have performed some very important research in this area that has not been published in book form up to now. After an introduction of the two concepts of light-source color rendering – color fidelity and color preference – the authors enumerate the well-known problems of the currently used CIE test method and provide a very short overview of the models proposed by different authors for a new color-rendering metric, but do not evaluate the advantages and disadvantages of these. Here, again, are the descriptions of the experiments of the authors to assess the properties of color quality of illuminated scenes. The strength of the chapter is that the very important research results of the authors of the book are summarized in one place. Based on these results, one can expect that both the authors and some other research groups will further develop new light-source color-quality descriptors.

The final chapter of the book discusses emerging visual technologies such as flexible displays, laser and LED displays, and projectors. Topics include the color changes observed with LED aging and dimming, and some hints are provided with regard to indoor light sources, such as accent lighting, and the influence of circadian rhythms with light.

Every chapter has its own bibliography with, in some cases, over 50 entries, and a very large number of figures, with many figures in color. Good-quality color figures should really serve to make the content of the book more understandable.

In summary, this work is unique and should be on the bookshelf of every scholar and developer of color displays. Both the overviews of the general literature, provided by real experts in the subject, and the description of their own research work, make it an important reading piece that cannot be found elsewhere.

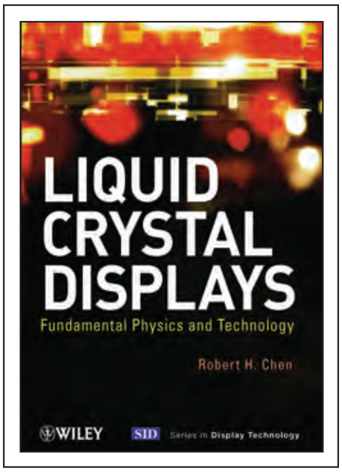
Dr. János Schanda is Professor Emeritus at the University of Pannonia, Hungary. He graduated in physics from the Loránd Eötvös University in Budapest. The Hungarian Academy of Sciences granted him the degree of "Doctor of Technical Sciences" for his thesis work on color rendering. He is past VP Technical of th e CIE and is on the editorial/international advisory board of Color Research & Applications, USA; Light & Engineering, Russia; Lighting Research & Technology, UK; and Journal of Light & Visual Environment, *Japan. Since 2010 he has been a member of the Advisory Board of the Colour & Imaging Institute, Art & Science Research Centre, Tsinghua University, China, and since 2011 a member of the Centre for Colour Culture and Informatics (C3I) of Taiwan. In 2010, the British Colour Group awarded him the Newton Medal and in 2011, CIE presented him the "De Boer Pin." He is the author of over 600 technical papers and conference lectures.*

Liquid Crystal Displays: Fundamental Physics and Technology

by Robert H. Chen
Reviewed by Birendra Bahadur
SID–Wiley Series

As a well-established, mature, high-performance technology, liquid-crystal displays (LCDs) have become an indispensable part of our lives. It is by far the largest display technology and is used in simple devices such as watches, calculators, clocks, handheld games, and medical and retail monitors to complex applications such as mobile phones, laptops, desktops, TVs, medical imaging, digital signage, avionics, and military equipment. LCDs constitute more than 80% of the over-$100-billion display market.

The LCD journey began in the late 1960s and has undergone many interesting developments and phases during the last 45 years. In *Liquid Crystal Displays: Fundamental Physics and Technology*, author Robert Chen describes this journey extremely well. There are many fine books on LCDs, but this one is unique in that it not only discusses the physics, chemistry, and technology of LCDs, but throws light on historical developments as well. Numerous witty footnotes of historical and technical relevance are included, which make the reading enjoyable as well as fascinating. Another unique aspect is that the author begins with a description of fundamental physics and mathematics in order to explain the complex theory and science of LCDs in a simple way. Chen is able to link many LCD developments with earlier physics and optics work and with more than 100 years of liquid-crystal research.



The book is divided into 27 chapters and can be read at several different levels – by someone relatively unversed in the concepts of high-level physics and by professionals in the field. The first through the 11th chapters are basically introductory. Although it is advisable to read all the chapters in sequence for continuity, a college-educated physicist or electrical engineer could skip the first four chapters on double refraction, electromagnetism, light in matter, and the polarization of electromagnetic waves. The book then turns to a brief description of the history, types, physical properties, and order parameter of liquid crystals, then proceeds to the thermo-dynamics of liquid crystals and the calculus of variations.

Subsequent sections describe different theories of liquid crystals and the derivation of many display parameters. Included are discussions of the Landau–de Gennes theory and the mean field concepts leading to the Maier– Saupe theory and its extension. The author describes the static continuum theory and the splay, bend, and twist elastic constants that led to derivations of threshold voltages for the Fréedericksz transition, twisted-nematic (TN), and in-plane-switching (IPS) cells. He also covers the dynamic continuum theory (Ericksen– Leslie) and derives the switching times of LCDs.

One chapter deals with the historically important but currently obsolete topic of dynamic scattering. Later topics include liquid-crystal chemistry and mixture formulation, with emphasis on the early developments, ownership claims, and patent controversies around TN-LCDs. The author also looks at the limitations of TN displays for high-level multiplexing and the advent of super-twisted-nematic (STN) and active-matrix LCDs. One unique chapter covers the historic and cultural background of the development of notebook screens. The next chapter, which might be skipped by an engineering graduate student, covers the basics and history of transistors and ICs. The author then proceeds to a description of active-matrix and TFT fabrication, and then to gray scales, color filters, signal processing, and backlights (fluorescent as well as LEDs). The physics of compensation films for widening viewing angles and reducing image inversions are described, as are popular LCD modes for TV applications, including multi-domain vertical alignment (MVA) and IPS and their variants. Response-time issues such as slow response and flicker for TN, MVA, and IPS modes are examined, along with methods (such as overdrive schemes) used to improve them. The LCD fabrication process is very well described, and so is the global LCD business, with a discussion of the impact of the cultural, national, and business background of companies on LCD development and manufacturing. The final chapter describes new display technologies such as OLEDs, electrophoretic, PSCT, and blue phase, as well as newer applications including touch screens and 3-D.

The book is well written and very useful. The photographs and figures are informative and clear. The basic science, physics, optics, chemistry, technology, and historical developments and manufacturing of LCDs are described clearly. Numerous electro-optical effects are helpfully outlined as well. The main drawback is a lack of references for LCD researchers. The author also did not refer to many well-known early LCD books and review articles. However, as a textbook, it serves an excellent purpose. Everyone, from beginner to advanced researcher, will find *Liquid Crystal Displays: Fundamental Physics and Technology* rewarding as well as interesting. It should serve as an important textbook for advanced undergraduate and graduate students interested in LCDs, and I strongly recommend it to anyone interested in LCDs. ■

***Dr. Birendra Bahadur** is a Principal Engineer with the Headdown Display Center at Rockwell Collins, Inc., in Cedar Rapids, IA. He is an internationally recognized researcher in LCDs and other displays, with 85 papers and four books published to date (http://www. sid.org/AboutSID/LeadershipGovernance/BirendraBahadur.aspx). He began working on liquid crystals and LCDs in 1969 for his Ph.D. thesis. During his career, he has developed and manufactured over 500 types of custom and standard passive- and active-matrix LCDs for consumer, industrial, telecommunications, agriculture, automobile, avionics, and military applications.*

editorial

continued from page 2

dizzying array of highlights that covers much more than any one of us could have gleaned on our own. Their full-length features each appear in this issue and I hope you find them as exciting to read as I did.

Incidentally, you may be wondering why I did not include touch technology in the aforementioned list. In fact, industry expert Geoff Walker also did a great job for us capturing the essence of almost 100 exhibits and presentations focused on touch. We're running his Display Week review along with an entire issue guest edited by Geoff devoted to touch technology next month (September). It looks to be an outstanding issue in the making.

I can't recall the first time I truly understood the mechanism by which a radio signal in the air became a picture on the TV set in my house, but I know I was always more fascinated with the "how?" than with any other aspect of the process. In high school I studied all the texts I could find on television and CRT technology, at times stumbling onto the publications of people I didn't know but would eventually meet many years later through SID. Using this knowledge, I stared at those glowing tubes and wires, trying to envision each step in the signal chain, always coming to the CRT display as the single most fascinating and compelling part.

My first professional job was in the display systems group at Raytheon Company, where I was privileged to be mentored by several people who in their careers had made great contributions to the field of CRTs. Through them I learned optical metrology, color science, electromagnetics, and many other important core skills that I still use today in my work. Without those mentors, and the opportunity to join SID, I never would have had the chance to contribute to so many exciting product developments and technology achievements during my career. Being able to ask questions and learn through the experiences of those in our field was more valuable than all the formal education I received.

That's why membership and involvement in the Society is more important now than it ever was. The display field grows in new directions and with exponential progress every year. The number of things any developer needs to know in order to efficiently implement good display designs, let alone create new displays, gets more daunting all the time. That's why we, as seasoned members of the industry, have an obligation to continue to mentor as much as we are able. Find the people in your company or institution who are curious and make time to teach them as much as you can. Direct them to the vast array of archived publications, invite them to local chapter meetings, and enable them to attend the annual SID events. You never know where the next Karl Ferdinand Braun, Jan Rajchman, Otto Schade, or Slottow–Owaki prize winner may come from. She could be the new junior scientist in your research group looking at a new polymer material, or the guy who sits in the back of the next chapter meeting wishing he knew a way to bring real-time holograms into your living room. SID members have a long and honorable history of supporting technical education and giving generously of their time and abilities to mentor others.

If the past 50 years of SID could be summed up by any one observation, I think it should be that the legacy of the last 50 years of vast achievements is not just the discoveries and inventions themselves, but the countless new generations of innovators who are succeeding now because of the enthusiastic training and mentoring of those who came before them. This will be the lasting legacy of the early visionaries who brought our Society to life. Such enthusiasm is vital not only for the health of the display industry, but for the longevity of SID itself. If you have been around long enough, you know that the success of the industry and the Society are deeply connected with each other. I hope that those of us active in the industry right now, busy as we are, will take the time to encourage and mentor the promising young display technologists among us. In this way, we not only share our own knowledge but that of the industry luminaries who came before us, and thus contribute to the incredible new developments that will happen during our lifetimes and beyond.

Here's to 50 years, and counting, of the Society for Information Display. May it prosper for at least 50 more. ■

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